SAA09FY091-001
Rev. C
December 2004

SYSTEM ASSURANCE ANALYSIS

OF THE

30-TON BRIDGE CRANES

AT THE

ORBITER PROCESSING FACILITY,

HIGH BAYS 1 AND 2

Baseline No.: 380.00 PMN: H70-1379

United Space Alliance

GROUND OPERATIONS

Revision Log

Rev.	Description	Date
A	General update and rewrite to review the system to assure components were properly identified and categorized, that the categorization still applies, that the effect on the system remains the same, and to include and categorize new components. Added "BRIDGE" to title. No RIDs were generated for this system by GERB Team A15, only a recommendation addressed in section 6.2, Areas of Concern.	August 1988
B	Revised to include Documentation of 1R items.	April 1992
C	In response to PRCBD S064060, Raising the Bar Initiative (SSP-9) FMEA/CIL Review, deleted groundrule stating that contact with flight hardware would not cause damage. EO-1 & EO-2 have been incorporated into this revision.	12/16/04

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1.1 FINDINGS

Table 1. Finding Summary

	Assessment
Reliability Criticality	Critical
Safety Criticality	Critical

	Type	Quantity
Critical Items	1	-
	1S	-
	2	-
1R Non-CIL Items	1R	8
Critical Flexhoses	1S	-
	2	8
Critical Orifices	1S	-
	2	-
Critical Filters	1S	-
	2	-
Hazard Reports	Accepted Risk	-
	Controlled	3

1.2 AREAS OF CONCERN

There were no Areas of Concern identified with this system.

1.3 DOCUMENTATION LIST

Document/Drawing No.	Title
NSTS 22206	Requirements for Preparation and Approval of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL)
NSTS 22254	Methodology for Conduct of NSTS Hazard Analyses
79K16771	Electrical Schematic, OPF High Bay, 30-Ton Overhead Traveling Crane
79K16825	Mechanical Arrangement 30-Ton Bridge Crane OPF
79K10641	RF Comm. Instl. – OPF Cranes
79K05594	OPF 30-Ton Crane
1205-2	Trolley General, 30-Ton Capacity. Overhead Traveling Crane, Fulton
1205-3	Hoist Assembly, 30-Ton Capacity. Overhead Traveling Crane, Fulton
1205-3A	Drum Double Block Brake Assembly, 30-Ton Capacity. Overhead Traveling Crane, Fulton
NASA-STD-8719.9	NASA Safety Standard for Lifting Devices and Equipment
VEN 203	Operation Instructions and Parts Manual OPF 30-Ton Crane (Fulton; FSCM-309; Contract No. NAS 10-8855)

Document/Drawing No.	Title
OMI V5008.003	FRCS Installation on Orbiter
OMI Q3119	30 Ton Bridge Cranes, OPF (Operation)
OMI Q6158	Maintenance Instructions for the 30 Ton Bridge Cranes
79K16479	General Operations and Maintenance Requirements and Specifications Document for Load Sensitive Cranes and Hoists
79K80260	Hose Assembly Specification
SK-78-HL-14484	OPF 30-Ton Overhead Crane Overspeed Brake Hydraulic System
KHB 1710.2	KSC Safety Practices Handbook
USA002433	Operating Procedure - Energy Control Program: Lockout/Tagout Requirements For Servicing Equipment and Machinery

2 SYSTEM DESCRIPTION

2.1 GENERAL

The 30-Ton Bridge Cranes in OPF High Bays 1 and 2 are used to raise, lower and provide lateral East/West or North/South directional movement of Orbiter payloads, flight hardware, and Ground Support Equipment. There are two bridge cranes in each of the two high bays. Each of the four cranes includes a bridge, trolley, and hoist subsystem. Each crane is a double girder, double rail bridge crane spanning 141 feet 6-1/4 inches. The bridges move in North/South directions on parallel rails fixed to the structure of the high bay. The trolleys move in East/West directions on rails mounted on each bridge structure. Each trolley carries a complete hoist assembly that has a capacity of 30 tons. The cranes are powered by 480 Volts of 60-Hz electrical power that is supplied by the OPF facility. A general arrangement is shown in Figure 1.

2.2 HOIST

The purpose of the hoist assembly is to lift, lower, and hold the load suspended from the load hook. The hoist subsystem drive unit consists of a speed reducer, holding brake, drum, emergency drum band brake, load block sheave assembly, and wire rope. A figure of the hoisting subsystem is shown in Figure 2. The drive unit consists of a two-speed pony motor, reduction gear, clutch assembly, and a two-speed main motor. The drive unit is used to supply torque to the gear reducer via two motors. The pony motor transmits torque by way of a clutch through the main motor to the gear reducer during slow hoisting and lowering operations. The main motor transmits torque directly to the speed reducer during high-speed hoisting and lowering operations. The speed reducer increases and transmits torque to the drum and contains a mechanical load brake. An 8 part 1 piece reeving is used in conjunction with upper sheaves and lower load block assembly for torque conversion to linear translation of the hook (See Figure 5). A contamination cover is attached to the load block. The main motor brake is attached to the south side output of the speed reducer and an emergency drum band brake is attached to the north side of the wire rope drum. The emergency drum band brake is spring loaded, hydraulic released and is activated by an overspeed switch or an E-stop.

2.3 TROLLEY

The trolley subsystem travels east to west over at 10-foot 0-inch wide track on the bridge and the drive unit consists of a gear reducer, main motor brake, couplings and drive wheels. The drive unit consists of a single speed pony motor, clutch, and two speed main motor. The clutch transmits torque from the pony motor through the main motor to the trolley gear reducer during slow-speed operations. The main motor transmits torque directly to the gear reducer during high-speed operations. The gear reducer increases and transmits torque to the drive wheels via shaft and flex-coupling assemblies. A motor brake

is located on the north side of the gear reducer. Figure 3 shows the configuration of the trolley subsystem.

2.4 BRIDGE

The purpose of the bridge drive assembly is to move the 30-ton bridge crane laterally, North/South, across the length of the OPF High Bay. The bridge subsystem drive units (2) consist of two gear reducers, two bridge brakes (east and west), a squaring shaft, couplings, pillow bearings, and drive wheels. The drive units, one on each side of the bridge, consist of a single speed pony motor, clutch, and a two-speed main motor. The clutch transmits torque from the pony motor through the main motor to the gear reducer during slow-speed operations. Both drive units are activated and the main motor transmits torque directly to the gear reducer during high-speed operations. The gear reducer increases and transmits torque to the squaring shaft and drive wheels via flex-couple assemblies. The drive mechanisms on each side of the bridge are activated simultaneously for translation motion and the squaring shaft prevents binding or misalignment of the bridge motion. The motor brakes are located on the squaring shaft side of the gear reducers. Figure 4 shows the configuration of the bridge subsystem.

2.5 ATTACHMENTS AND SUPPORT MECHANISMS

All gear shaft or coupling shaft attachments are either integral, keyed in place, supplied, or press fit in the hoist, trolley and bridge subsystems. Pillow bearings are used to support the squaring shaft in the bridge mechanism and the drum in the hoisting mechanism. The operator's cab and electrical panels are mounted on the bridge structure. The electrical cables are managed by a pivoting cable track for trolley translation and a conductive track and shoe mechanism is used for the bridge cables during bridge translation.

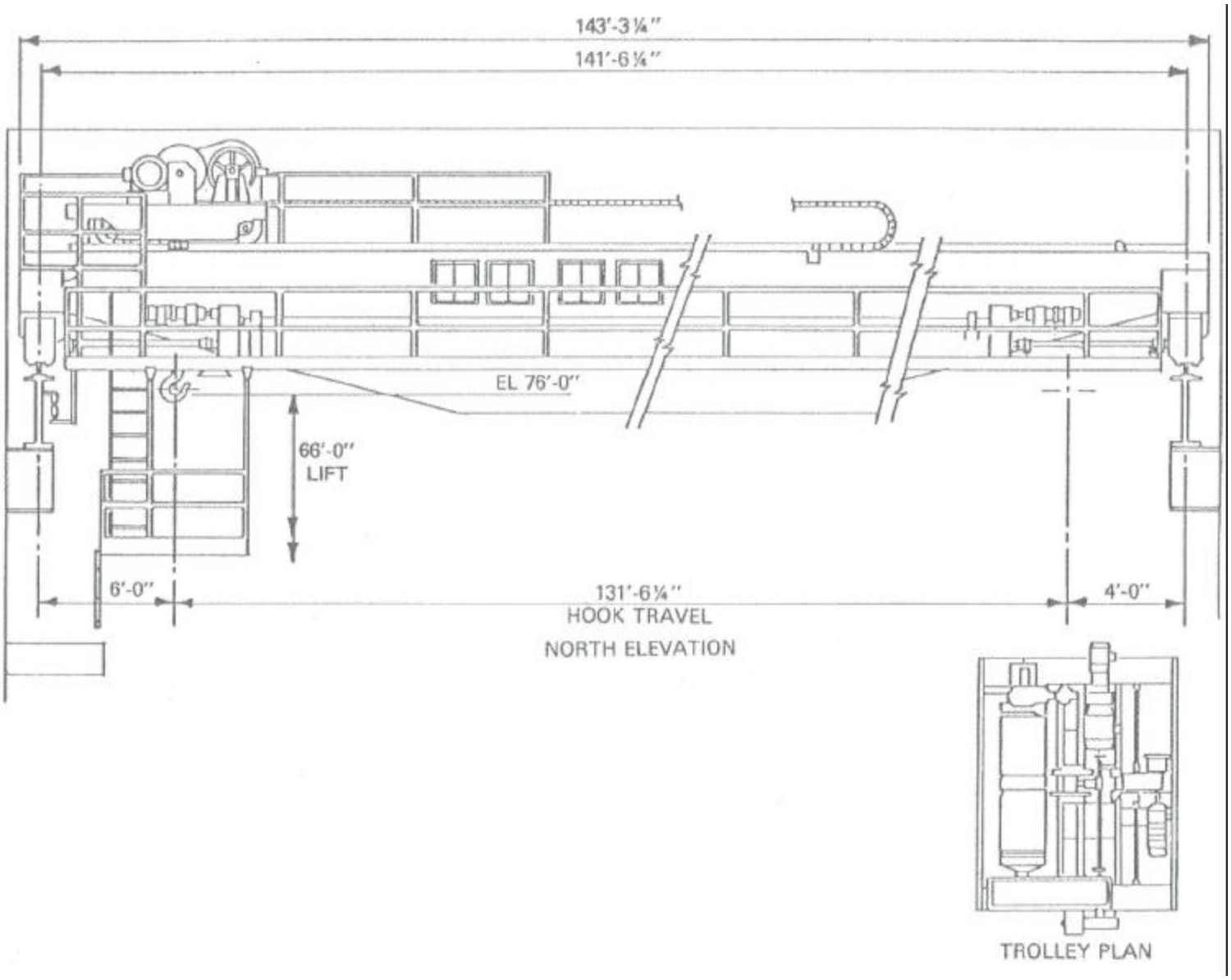

Figure 1. 30-Ton Bridge Cranes, General Views

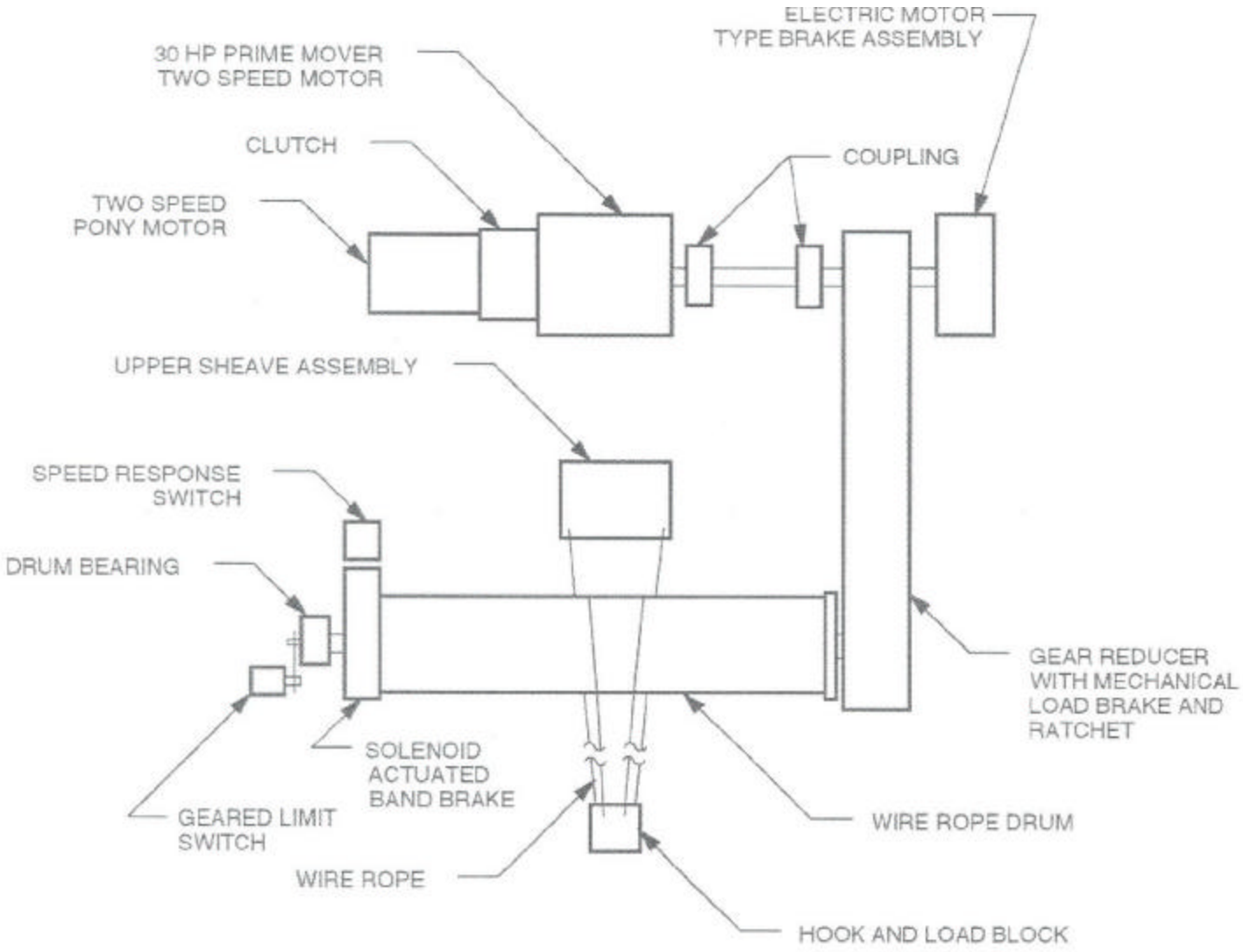

Figure 2. 30-Ton Bridge Cranes, Hoist Assembly

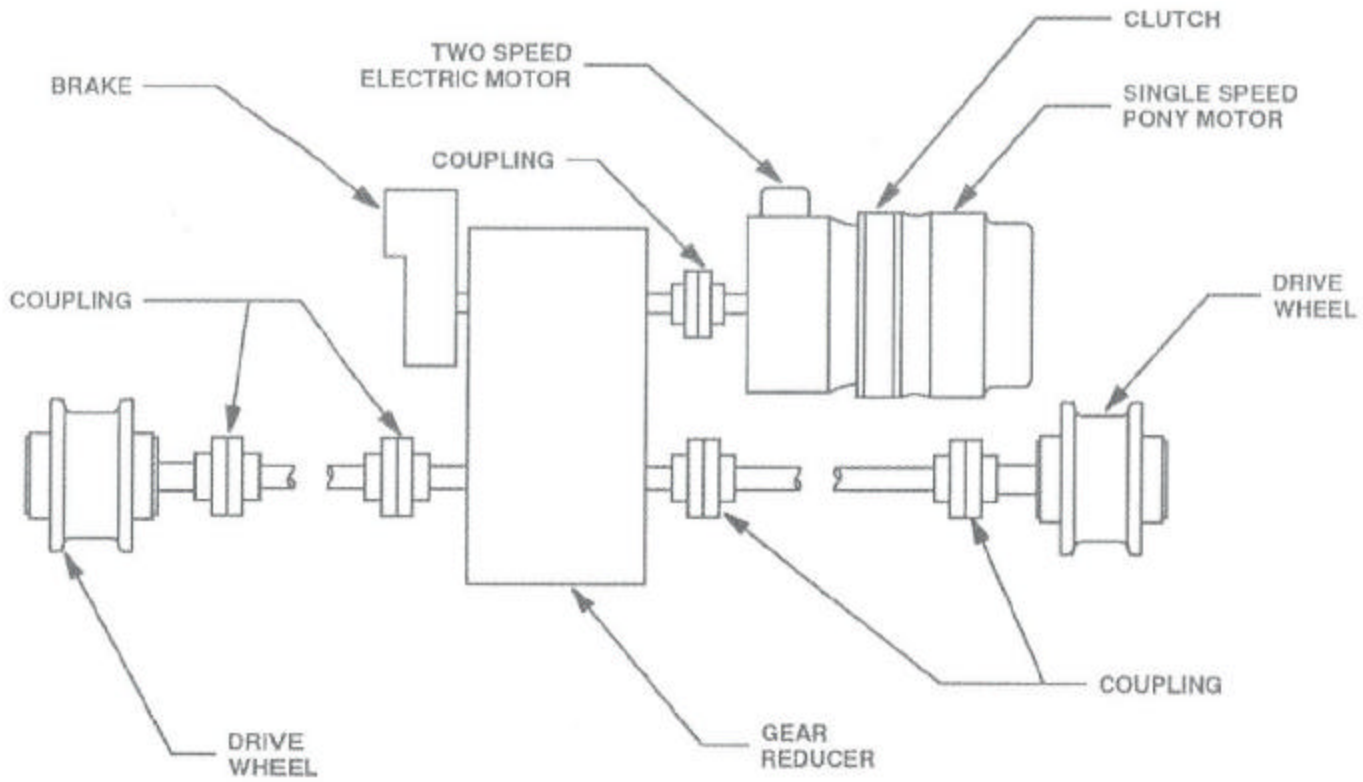

Figure 3. 30-Ton Bridge Cranes, Trolley Drive Diagram

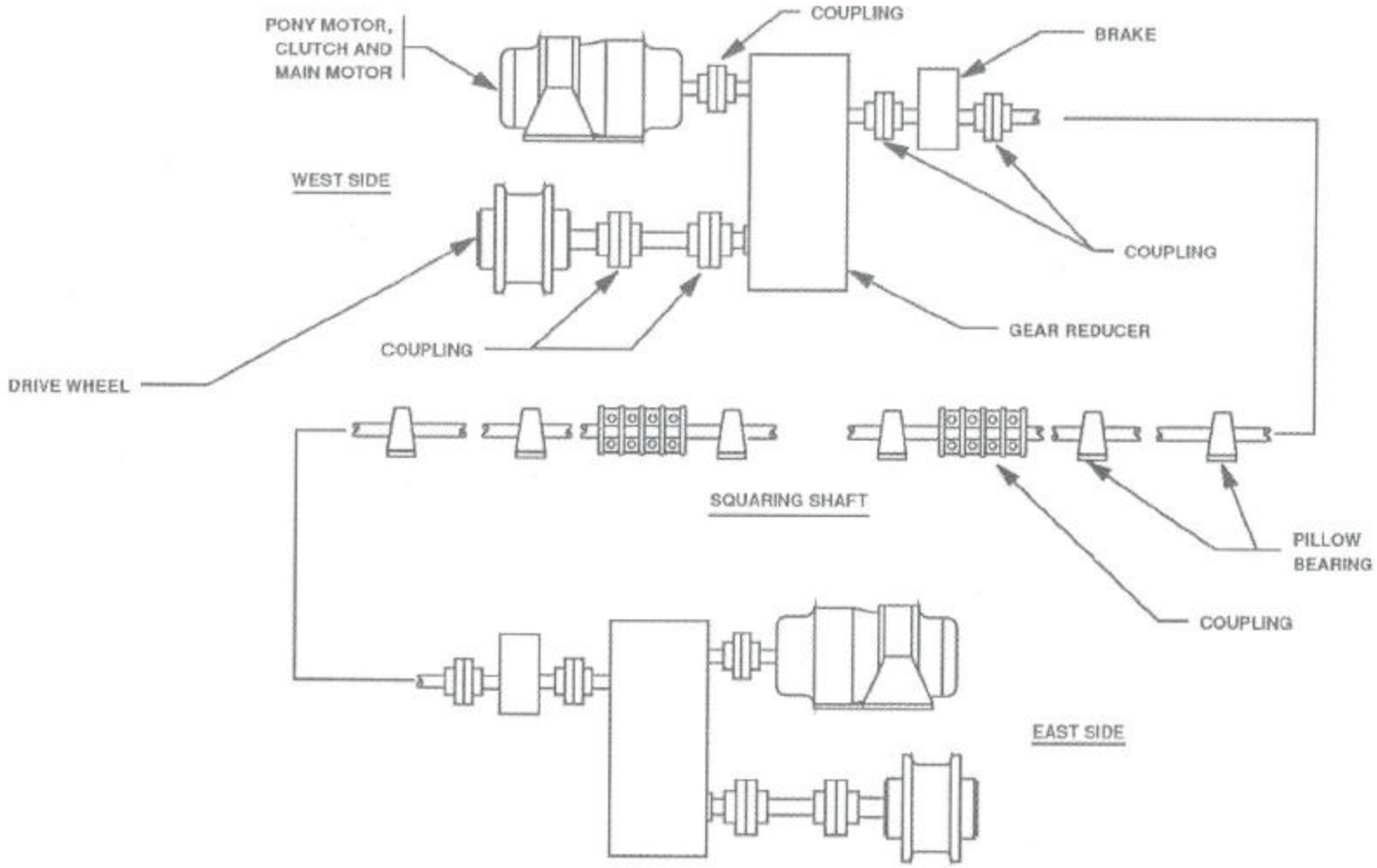

Figure 4. 30-Ton Bridge Cranes, Bridge Drive Assembly

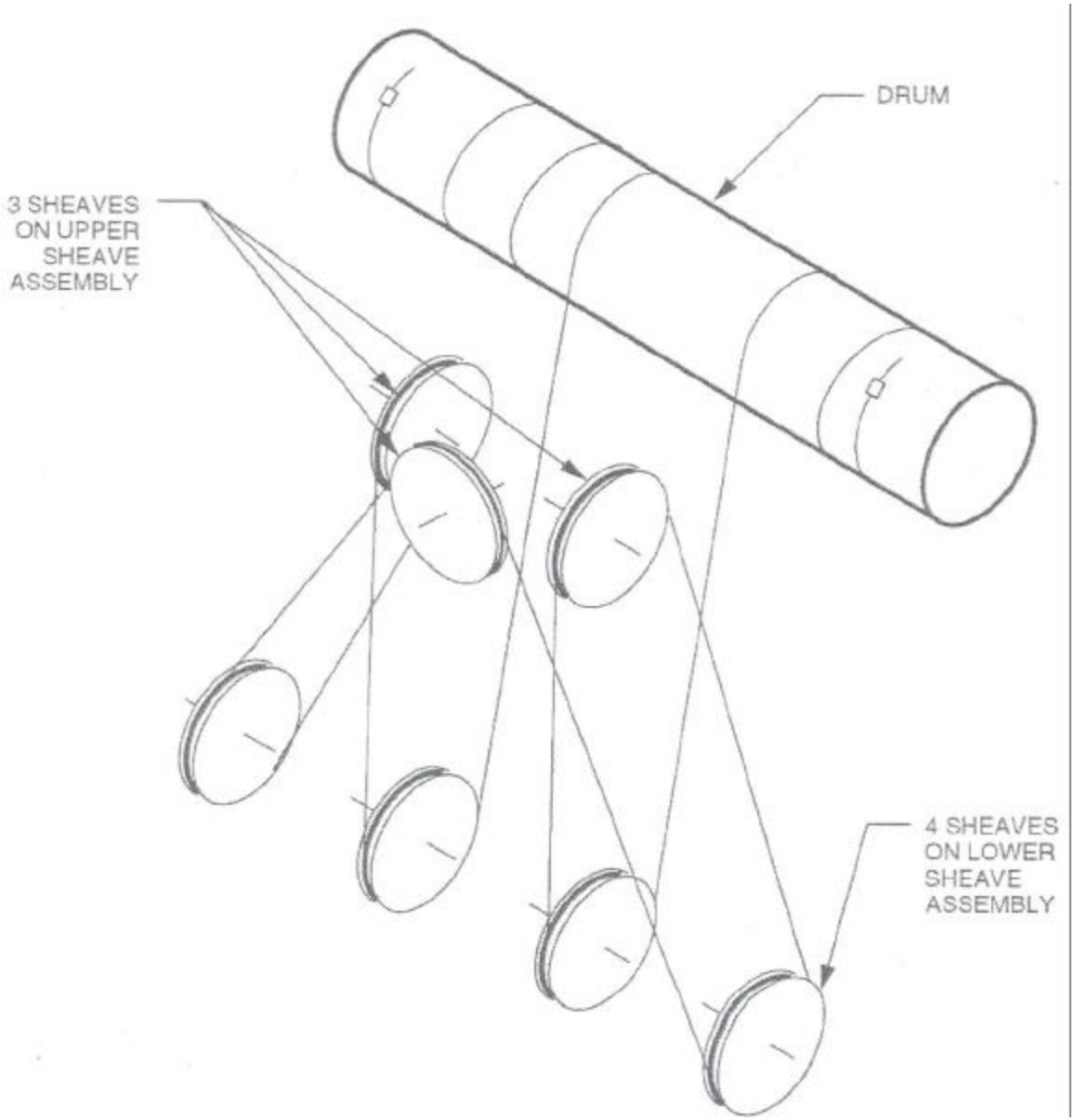

Figure 5. 30-Ton Bridge Cranes, Rope Reeving Assembly

3 ANALYSIS GROUNDRULES

This analysis has been developed in accordance with NSTS 22206 and NSTS 22254.

The following additional groundrules and assumptions were used during this analysis:

a. It is assumed the 30-Ton Crane Operators are trained and properly certified and will therefore take appropriate correcting action in the event of a system malfunction.

b. It is assumed that the lowest speed range and speed will be selected for operation of the 30-Ton Bridge Cranes at close proximity to flight hardware (i.e., 3 feet or less).

4 FAILURE MODES AND EFFECTS ANALYSIS

4.1 CRITICALITY ASSESSMENT

The system functions are identified in Figure 6, Functions Block Diagram, and assessed on the following Criticality Assessment Worksheet.

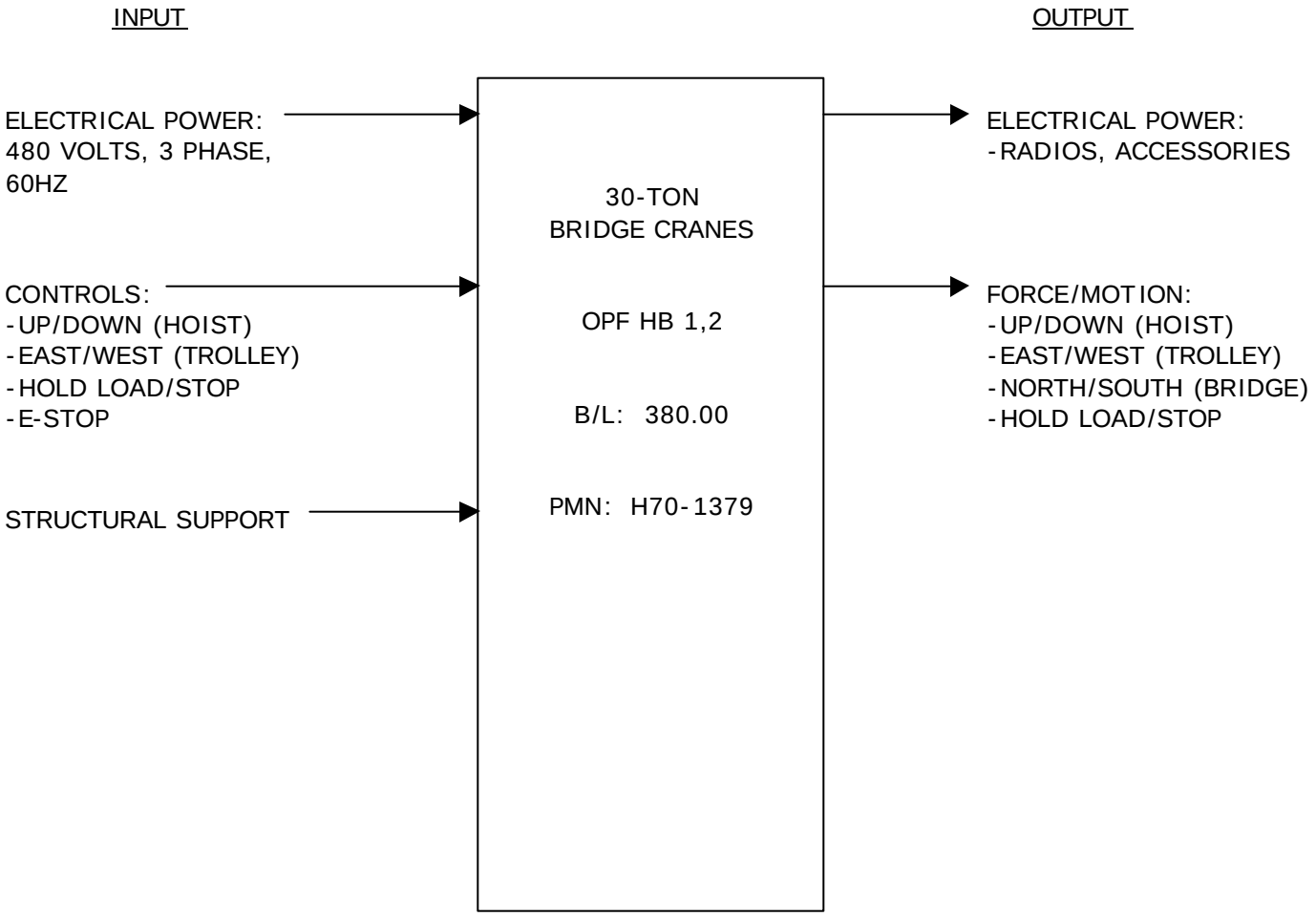

Figure 6. 30-Ton Bridge Cranes, Function Block Diagram

Table 2. Criticality Assessment Worksheet – H70-1379					Pages 14 to 15
System/Subsystem: 30-Ton Bridge Cranes **Location:** OPF High Bays 1 and 2					**Baseline Number:** 380.00
Input/ Output	**Function**	**Time Period**	**Effect of Loss/Failure** If Function Fails to Operate or Cease Operation on Time, Fails During Operation, and/or Prematurely Operates	**Crit/ Noncrit**	**Notes**
Input					
Electric Power -480 Volts, 3 Phase, 60Hz AC	Supplies power to operate motors and brakes for hoist, trolley, and bridge.	During crane operations.	Failure of electric power will cause a delay in operations.	NC	See SAA09EL22-002/B.
Operator Controls	Operates hoist, bridge and trolley in specified direction for lifting, lowering, and holding of loads.	As required.	Failure during operation of hoist could cause load to continue moving in the specified direction and could result in damage to a vehicle system.	C	See Hazards Analysis.
Structural Support	Structural support of the load by the bridge, trolley, and rails.	As required.	Failure of crane structural supports could cause loss of ability to support 30-ton bridge crane.	C	FMEA not required per NSTS 22206 Rev C.
Output					
Electrical Power -Communication	Supply 120 Volts AC to radios and accessories.	As required.	Failure of electrical power to radios and accessories (for communication between crane operators) could cause damage to a vehicle system.	C	See FMEA.
Force/Motion -Up/Down (Hoist)	Raise, lower and position flight hardware.	As required.	Failure during operation of hoist could cause load to continue moving in the specified direction and could result in damage to flight hardware or a vehicle system.	C	See FMEA.
-East/West (Trolley)	Position flight hardware.	As required.	Failure during operation of trolley could cause load to continue moving in the specified direction and could result in damage to flight hardware or a vehicle system.	C	See FMEA.
-North/South (Bridge)	Position flight hardware.	As required.	Failure during operation of bridge could cause load to continue moving in the specified direction and could result in damage to flight hardware or a vehicle system.	C	See FMEA.

Table 2. Criticality Assessment Worksheet – H70-1379					Pages 14 to 15
System/Subsystem: 30-Ton Bridge Cranes **Location:** OPF High Bays 1 and 2					**Baseline Number:** 380.00
Input/ Output	**Function**	**Time Period**	**Effect of Loss/Failure** If Function Fails to Operate or Cease Operation on Time, Fails During Operation, and/or Prematurely Operates	**Crit/ Noncrit**	**Notes**
-Hold load/stop (Hoist/Trolley/Bridge)	Stop and hold load in a fixed position.	As required.	Failure of hoist/trolley/bridge to cease operation after stopping or while holding load could cause possible loss of life and/or a vehicle or damage to a vehicle system.	C	See FMEA.

4.2 FMEA WORKSHEETS

The Failure Modes and Effects Analysis follows.

4.2.1 Passive Components

Passive items are components that may be necessary for the performance of the system but do not change state during critical operations, or static structural members that do not transfer an applied force to an object to make the object move in some manner, unless otherwise accepted in NSTS 22206 as a passive component.

The following components were considered passive in the analysis:

Table 3. Passive Component List

Item	Rationale
Hook, Load Block, Wire Rope, Sheaves, Rope Drum	These components accepted as passive per NSTS 22206 paragraph 4.5.1.g. However, the drum shafts shall be analyzed as to the attachment method.

The Hazard Analysis contains passive components that constitute a safety concern.

4.2.2 Wire Harnesses, Cables and Connectors

There are no wire harnesses, cables, or connectors associated with the analysis for this system.

Table 4. FMEA – 30-Ton Bridge Crane – Mechanical Hoist Drive Assembly						Pages 17 to 20
System/Subsystem: 30-Ton Bridge Cranes/Hoist Drive Assembly **PMN:** H70-1379					**Drawing No.:** 79K16825 **Reference:** Drawing in Document	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
Reuland 10690-XA0869AB	Reduction gear (Pony motor)	Double and triple reduction helical motor reducer between pony motor and clutch	Gear disengagement	The mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3
Sier-Bath F-1-1/2	Coupling, Flex-rigid (2)	Provides mechanical link between the floating shaft and hoist main motor speed reducer.	Coupling hubs disengage	Floating shaft will not turn; hoist will not operate. Main holding brake and/or the mechanical load brake will stop/hold the load. Delay in operations.	No effect.	3
			Key disengagement	Floating shaft will not turn; hoist will not operate. Main holding brake and/or the mechanical load brake will stop/hold the load. Delay in operations.	No effect.	3
(See Fulton drawing 1205-3)	Gearbox (Hoist main motor)	Transmits torque from hoist main motor to wire rope drum.	a. Gear disengagement b. Structural failure c. 09FY091-001.001 d. Abnormal hoist motion e. N/A f. Immediate g. N/A	Noisy and/or jerky operation of hoist. If severity of failure is great enough, load may be dropped. Over-speed sensor automatically sets emergency drum band brake on drum and will hold load. Delay in operations.	Subsequent failure of the emergency drum band brake to set could result in dropping flight hardware, potentially under suspended load operations. Possible loss of life and/or vehicle.	1R

Table 4. FMEA – 30-Ton Bridge Crane – Mechanical Hoist Drive Assembly						Pages 17 to 20
System/Subsystem: 30-Ton Bridge Cranes/Hoist Drive Assembly **PMN:** H70-1379					**Drawing No.:** 79K16825 **Reference:** Drawing in Document	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
GE 3641051	Holding brake	Stops 30-ton hoist action when hoist main motor is de-energized. (See also Electrical FMEA)	Fails to disengage	Hoist will remain stopped. Delay in operations.	No effect.	3
			Fails to engage	If the main holding brake fails to engage, the mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3
(See Fulton drawing 1205-3)	Load brake	The double disc ratchet brake holds and controls the load speed in the lowering direction only.	Pawl fails disengaged	The load will lower faster than normal, but not an uncontrolled freefall. The crane operator can let go of the joystick, which will apply the holding brake, or the e-stop observer can press the e-stop button, activating the emergency brake.	No effect.	3
			Pawl fails engaged	Pawl will not release off the ratchet wheel, but will still operate.	No effect.	3
			Discs fail disengaged	The load will lower faster than normal, but not an uncontrolled freefall. The crane operator can let go of the joystick, which will apply the holding brake, or the e-stop observer can press the e-stop button, activating the emergency brake.	No effect.	3
			Discs fail engaged	Hoist main motor will overload and stall. Main holding brake will engage. Delay in operations.	No effect.	3

Table 4. FMEA – 30-Ton Bridge Crane – Mechanical Hoist Drive Assembly						Pages 17 to 20
System/Subsystem: 30-Ton Bridge Cranes/Hoist Drive Assembly **PMN:** H70-1379					**Drawing No.:** 79K16825 **Reference:** Drawing in Document	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
(See Fulton drawing 1205-3A)	Emergency drum band brake (spring loaded, hydraulic released)	Provides frictional braking torque directly to wire rope drum.	Fails to disengage	Hoist will not operate. Delay in operations.	No effect.	3
			a. Fails to engage b. Brake mechanism locked in disengaged position, SV-1 fails activated, over-speed switch fails closed, structural failure of band assembly or coil spring c. 09FY091-001.002 d. Abnormal hoist motion e. N/A f. Immediate g. N/A	Unable to set emergency drum band brake. Mechanical load brake and/or holding brake will engage and stop load.	Subsequent failure of the gearbox could result in dropping flight hardware, potentially under suspended load operations. Possible loss of life and/or vehicle.	1R
SV-1	Hydraulic valve (Sheet 3-G5)	Hydraulic valve with a solenoid coil that controls the dumping of hydraulic fluid from the emergency brake	Fails deactivated	No pressure to open the emergency drum band brake. Fluid returns to reservoir. Brakes will remain set. Crane will not operate. Delay in operations.	No effect.	3

Table 4. FMEA – 30-Ton Bridge Crane – Mechanical Hoist Drive Assembly						Pages 17 to 20
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Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			a. Fails activated b. Incorrect setting of the valve c. N/A d. Abnormal hoist motion e. N/A f. Immediate g. N/A	Pressure will remain on piston and emergency drum band brake will remain released.	No effect. Solenoid valve will be an emergency drum band brake failure cause. See emergency drum band brake.	3
(See Fulton drawing 1205-3A)	Drum shaft bearing	Supports and allows rotation of the wire rope drum.	Bearings seize	Drum shaft will not turn. Delay in operations.	No effect.	3

Table 5. FMEA – 30-Ton Bridge Crane – Mechanical Trolley Drive						Pages 21 to 21
System/Subsystem: 30-Ton Bridge Cranes/Trolley Drive **PMN:** H70-1379					**Drawing No.:** 79K16825 Sheet 1 **Reference:** Drawing in Document	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
Sier-Bath F-1	Coupling, Flex-rigid	Provides connection between the trolley main motor and gear reducer.	Key disengagement	Rolling friction will slow and stop the trolley. Delay in operations.	No effect.	3
			Coupling disengagement	Rolling friction will slow and stop the trolley. Delay in operations.	No effect.	3
Hansen DA41-ANBN-224	Gear reducer	Transmits torque from trolley main motor to trolley drive shafts.	Gear disengagement	Rolling friction will slow and stop the trolley. Delay in operations.	No effect.	3
GE 1C-3516-458AA00-1AA009	Trolley brake	Slows and stops trolley travel and holds trolley in position (See also Electrical FMEA)	Fails to engage	Rolling friction will slow and stop the trolley. Delay in operations.	No effect.	3
			Fails to disengage	Trolley inoperative. Delay in operations.	No effect.	3
Sier-Bath F-2	Coupling	Provides mechanical link between trolley gear reducer and trolley north drive shaft.	Key disengagement	Applying/setting trolley brake will result in braking only with the one drive shaft. Will only have drive with one wheel. It is possible to skew. Delay in operations.	No effect.	3
			Coupling disengagement	Applying/setting trolley brake will result in braking only with the one drive shaft. Will only have drive with one wheel. It is possible to skew. Delay in operations.	No effect.	3

Table 6. FMEA – 30-Ton Bridge Crane – Mechanical Bridge Drive						Pages 22 to 25
System/Subsystem: 30-Ton Bridge Cranes/Bridge Drive **PMN:** H70-1379					**Drawing No.:** 79K16825 **Reference:** Drawing in Document	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
Sier-Bath F-1	Coupling (3)	Provides mechanical link between bridge main motor #1 and gear reducer #1.	Key disengagement	No torque transmitted to gear reducer #1. Bridge main motor #2 will still move bridge. Delay in operations.	No effect.	3
			Gear disengagement	No torque transmitted to gear reducer #1. Bridge main motor #2 will still move bridge. Delay in operations.	No effect.	3
Hansen DC41-CR-323	Gear reducer #1	Transmits torque from bridge main motor #1 to bridge drive truck #1.	Gear disengagement	Loss of bridge drive #1 and bridge drive truck #1 connection to bridge drive brake #1. Bridge drive truck #2 brakes will slow/stop bridge travel.	No effect.	3
Sier-Bath F-3	Coupling (2)	Provides mechanical link between gear reducer #1 and floating shaft to bridge drive truck #1.	Key disengagement	No torque transmitted to drive truck #1. Delay in operations.	No effect.	3
			Gear disengagement	No torque transmitted to drive truck #1. Delay in operations.	No effect.	3
(See Fulton drawing 1205-6)	Drive truck #1	Provides directional movement of bridge, trolley, hoist and load on bridge rails.	Bearings seize	Bridge will move with hesitation or not at all. Delay in operations.	No effect.	3

Table 6. FMEA – 30-Ton Bridge Crane – Mechanical Bridge Drive						Pages 22 to 25
System/Subsystem: 30-Ton Bridge Cranes/Bridge Drive **PMN:** H70-1379					**Drawing No.:** 79K16825 **Reference:** Drawing in Document	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
GE 002AA017	Bridge brake #1 (west)	Holds, slows and stops bridge travel. (See also electrical FMEA)	Fails to engage	Applying/setting bridge brakes will not slow/stop bridge movement. Bridge with load will not be affected because of rolling friction and operational procedures. Brake #2 will stop bridge. Delay in operations.	No effect.	3
			Fails to disengage	Bridge main motor/pony motor will try to rotate shaft. Current will rise and trip circuit breaker. Bridge will not move. Delay in operations.	No effect.	3
Link belt 14549KA	Couplings (clamp type for squaring shaft)	Provides mechanical link between sections of squaring shaft.	Key disengagement	No torque transmitted from gear reducer #1 to gear reducer #2 and vice versa. Bridge may not stay square with rails. Delay in operations.	No effect.	3
			Clamp disengagement	No torque transmitted from gear reducer #1 to gear reducer #2 and vice versa. Bridge may not stay square with rails. Delay in operations.	No effect.	3
5963R-5X2055	Pillow block bearings	Provides support and bearing surface for rotation of squaring shaft.	Bearing seize	Rotation of squaring shaft slows or drags. Accelerated wear of shaft bridge may not stay square with rail. Delay in operations.	No effect.	3
Sier-Bath F-1	Coupling (3)	Provides mechanical link between bridge main motor #2 and gear reducer #2.	Key disengagement	No torque transmitted to gear reducer #2. Bridge main motor #1 will still move bridge. Delay in operations.	No effect.	3

Table 6. FMEA – 30-Ton Bridge Crane – Mechanical Bridge Drive						Pages 22 to 25
System/Subsystem: 30-Ton Bridge Cranes/Bridge Drive **PMN:** H70-1379					**Drawing No.:** 79K16825 **Reference:** Drawing in Document	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Gear disengagement	No torque transmitted to gear reducer #2. Bridge main motor #1 will still move bridge. Delay in operations.	No effect.	3
Hansen DC41-CR-323	Gear reducer #2	Transmits torque from bridge main motor to bridge drive truck #2.	Gear disengagement	Loss or bridge drive #2 and bridge drive truck #2 connection to bridge drive brake #2. Bridge drive truck #1 brakes will slow/stop bridge travel.	No effect.	3
Sier-Bath F-3	Coupling (2)	Provides mechanical link between gear reducer #2 and floating shaft to bridge drive truck #2.	Key disengagement	No torque transmitted to drive truck #2. Delay in operations.	No effect.	3
			Gear disengagement	No torque transmitted to drive truck #2. Delay in operations.	No effect.	3
(See Fulton drawing 1205-6)	Drive truck #2	Provides directional movement of bridge, trolley, hoist and load on bridge rails.	Bearings seize	Bridge will move with hesitation or not at all. Delay in operations. Wheel cannot roll. Delay in operations.	No effect.	3
GE 002AA0017	Bridge brake #1 (east)	Holds, slows and stops bridge travel. (See also electrical FMEA)	Fails to engage	Applying/setting bridge brakes will not slow/stop bridge movement. Bridge with load will not be affected because of rolling friction and operational procedures. Brake #1 will stop bridge. Delay in operations.	No effect.	3

Table 6. FMEA – 30-Ton Bridge Crane – Mechanical Bridge Drive						Pages 22 to 25
System/Subsystem: 30-Ton Bridge Cranes/Bridge Drive **PMN:** H70-1379					**Drawing No.:** 79K16825 **Reference:** Drawing in Document	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails to disengage	Bridge main motor/pony motor will try to rotate shaft. Current will rise and trip circuit breaker. Bridge will not move. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
CB1	AC Circuit Breaker: 100A, 480V, 3-Phase, 60-Hertz with shunt trip coil (Sheet 5-E8)	Main circuit breaker for all crane operations.	Premature trip	Premature opening will result in loss of AC power to hoist, trolley, and bridge operations. Crane will not operate. Delay in operations.	No effect.	3
			Fails to trip	Damage to electrical conductors. Downstream circuit breakers will protect hoist, trolley and bridge motors, brakes, and clutches. Delay in operations.	No effect.	3
CB2	AC Circuit Breaker: 15A, 480V, single-phase, 60-Hertz (Sheet 5-E8)	Main circuit breaker for control circuitry.	Premature trip	Premature opening will result in loss of AC power to all control circuitry. Brakes will be applied on hoist, trolley and bridge. Delay in operations.	No effect.	3
			Fails to trip	Damage to downstream step-down transformer. Downstream fuse will protect secondary circuits. Loss of control circuitry. Delay in operations.	No effect.	3
CB3	AC Circuit Breaker: 50A, 480V, 3-Phase, 60-Hertz (Sheet 5-D8)	Main circuit breaker for hoist pony motor and main motor wiring.	Premature trip	Premature opening will result in loss of AC power to hoist main motor, pony motor, brake coil, and clutch coil. Brakes will set. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails to trip	Damage to electrical conductors. Downstream circuit breaker will protect hoist pony motor. Thermal overloads between CB3 and hoist main motor will provide delayed motor protection. Delay in operations.	No effect.	3
CB4	AC Circuit Breaker: 50A, 480V, 3-Phase, 60-Hertz (Sheet 5-C7)	Main circuit breaker for the hoist pony motor and hoist brake clutch coil rectifier wiring.	Premature trip	Premature opening will result in loss of AC power to the hoist pony motor, hoist holding brake and clutch coil rectifier. Brake will set. Delay in operations.	No effect.	3
			Fails to trip	Damage to electrical conductors only. Downstream fuses or thermal overloads will protect hoist pony motor, hoist holding brake and clutch coil rectifier. Delay in operations.	No effect.	3
CB5	AC Circuit Breaker: 7A, 480V, 3-Phase, 60-Hertz (Sheet 5-H4)	Main circuit breaker for the trolley assembly wiring.	Premature trip	Premature opening will result in loss of AC power to the trolley motor, pony motor, brake coil and clutch coil. Delay in operations.	No effect.	3
			Fails to trip	Damage to electrical conductors. Downstream thermal overloads will protect the main motor and circuit breakers will protect the pony motor, brake coil and clutch coil. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
CB6	AC Circuit Breaker: 3A, 480V, 3-Phase, 60-Hertz (Sheet 5-F4)	Circuit breaker for the trolley pony motor, brake coil and clutch coil wiring.	Premature trip	Premature opening will result in loss of AC power to the trolley pony motor, brake coil, and clutch coil wiring. Trolley brake will set. Delay in operations.	No effect.	3
			Fails to trip	Damage to electrical conductors. Downstream thermal overloads will protect the pony motor. Fuses will protect the trolley brake coil and clutch coil. Delay in operations.	No effect.	3
CB7	AC Circuit Breaker: 15A, 480V, 3-Phase, 60-Hertz (Sheet 5-D4)	Main circuit breaker for the bridge assembly wiring.	Premature trip	Premature opening will result in loss of AC power to the bridge motors, brake coils, pony motors, and clutch coils. Bridge brakes will set. Delay in operations.	No effect.	3
			Fails to trip	Damage to electrical conductors. Downstream thermal overloads will protect the bridge main motors. Circuit breakers will protect the pony motor, bridge brakes, and clutch coils. Delay in operations.	No effect.	3
CB8	AC Circuit Breaker: 15A, 480V, 3-Phase, 60-Hertz (Sheet 5-C4)	Main circuit breaker for bridge pony motors, clutch coils, and brake coils.	Premature trip	Premature opening will result in loss of AC power to bridge pony motors, brake coils and clutch coils. Bridge brakes will set. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails to trip	Damage to electrical conductors. Downstream thermal overloads will protect the bridge pony motors. Fuses will protect the bridge clutch coils and brake coils. Delay in operations.	No effect.	3
CB9	AC Circuit Breaker: 30A, 480V, 3-Phase, 60-Hertz (Sheet 5-F7)	Main circuit breaker for crane cab lighting transformer.	Premature trip	Premature opening will result in loss of AC power to lighting distribution panel, radio, and motor sensors. Operator will identify problem and stop crane operations. Delay in operations.	No effect.	3
			Fails to trip	Damage to electrical conductors. Downstream circuit breakers will protect lighting panel. Delay in operations.	No effect.	3
CB12	AC Circuit Breaker: 20A, 120V, 60-Hertz (Sheet 5-G6)	Individual circuit breakers for the motor sensors, radio, cab lights, and cab console.	Single premature trip	Premature opening will result in loss of AC power to the motor sensors, radio, cab lights, or cab console. Loss of power to motor heat sensors will turn on warning light and sound alarm. Joysticks for operation of hoist, trolley, and bridge will be disabled and motors de-energized. Redundant radio is still operational on a separate circuit breaker. E-stops are also available at the site of the operation if communication with the crane operator is lost.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails to trip	Damage to electrical conductors. Motor thermal overload switch would de-energize the motor when sensor activation temperature is reached. Delay in operations.	No effect.	3
M1 Reuland Frame 365U	AC motor; 30/11.25HP, 480V, 3-Phase, 60-Hertz (Sheet 5-D5)	Hoist main motor. A two-speed motor that provides and transmits torque to the output shaft and gear reducer. 1200/450RPM; squirrel cage.	Inoperative	Hoist will not move in fast speed. Pony motor can be used to move the hoist in the slow speed as long as the clutch is operational. The mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3
M2 Reuland Frame 256U	AC motor; 4/1.33HP, 480V, 3-Phase, 60-Hertz (Sheet 5-B5)	Hoist pony motor. A two-speed motor that provides and transmits torque to the output shaft/clutch hoist main motor. 1800/600RPM.	Inoperative	Hoist will not move in slow speed. Main motor can move the hoist in fast speed. The mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3
M3 Reuland Frame 213	AC Motor: 1/0.333HP, 480V, 3-Phase, 60-Hertz (Sheet 5-H1)	Trolley main motor. A two-speed motor that provides torque to the trolley gearbox for high-speed operation. 1800/600RPM; squirrel cage.	Inoperative	Trolley will not operate in fast speed. Pony motor can move trolley in slow speed as long as the clutch is operational. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
M4 Reuland Frame 23P	AC Motor: 1/8HP (Sheet 5-F2)	Trolley pony motor. One-speed motor that provides and transmits torque to the output shaft/clutch and trolley main motor. 1800RPM.	Inoperative	Trolley will not operate in slow speed. Trolley main motor can move the trolley in fast speed. Delay in operations.	No effect.	3
M5/M7 Reuland Frame 215	AC Motor: 2/0.66HP, 480V, 3-Phase, 60-Hertz (Sheet 5-D1, 5-E1)	Bridge main motors (2). A two-speed motor that provides torque to gear reducer and end trucks during high speed operations.	Inoperative	Bridge main motor will not provide torque for high-speed operation. Bridge brakes will be released. Bridge will move with second bridge main motor. Delay in operations.	No effect.	3
M6/M8 Reuland Frame 23P	AC Motor: 1/8HP (Sheet 5-C2)	Bridge pony motors (2). A one-speed motor that provides torque to the clutch/bridge main motor and gear reducer for truck ends.	Inoperative	Bridge pony motor will not provide torque for slow speed. Bridge brakes will be released. Bridge will move with second bridge pony motor. Delay in operations.	No effect.	3
M9/M10	Oil pump motor	To operate pump for bridge gearbox lubrication	Fails to operate	Lack of gearbox lubrication and accelerated wear.	No effect	3
T1	Transformer: 9KVA, 240/480V Primary, 3-Phase, 120/208V Secondary (Sheet 5-G6)	Step-down transformer that provides voltage for lighting distribution panel (motor sensors, radio, cab lights, or cab console lights)	Fails open	No current will travel to the lighting distribution panel. Motor sensors, radio, cab lights, and cab console lights will become inoperative. Operator will realize failure and stop crane operation. Delay in operations.	No effect.	3

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			Fails short	Unlimited current will travel through the transformer. Motor sensors, radio, cab lights, and cab console lights will become inoperative. Operator will realize failure and stop crane operations. Possible damage to GSE. Delay in operations.	No effect.	3
CT1	Transformer: Single-phase, 480V Primary (Sheet 5-A6)	Step-down transformer that provides voltage for the hoist pony motor clutch coil (90V at 0.5A)	Fails open	No current will travel to the hoist pony motor clutch coil. The mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3
			Fails short	Unlimited current will travel through the transformer and open fuse F6. No power will reach the hoist clutch coil and clutch will disengage. Hoist will not operate in slow speed. Delay in operations.	No effect.	3
CT2	Transformer: Single-phase, 480V Primary (Sheet 5-F2)	Step-down transformer that provides voltage for the trolley pony motor clutch coil (90V at 05.A)	Fails open	No current will travel to the trolley pony motor clutch coil. Trolley will not operate in slow speed. Delay in operations.	No effect.	3
			Fails short	Unlimited current will travel through the transformer and open fuse F11. No power will reach the trolley pony motor clutch coil and clutch will disengage. Trolley will not operate in slow speed. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
CT3	Transformer: Single-phase, 480V Primary (Sheet 5-A4)	Step-down transformer that provides voltage for the two bridge pony motor clutch coils (90V at 1A)	Fails open	No voltage will travel to the bridge pony motor clutch coil. Bridge will not operate in slow speed. Delay in operations.	No effect.	3
			Fail short	Unlimited current will travel through the transformer and open fuses F14 and F17. No power will reach the bridge pony motor clutch coils and clutches will disengage. Bridge will not operate in slow speed. Delay in operations.	No effect.	3
CT4	Transformer: 1KVA, 480V Primary, 120V Secondary Singe-phase, 60-Hertz (Sheet 3-H6)	Step-down transformer that provides voltage for all control circuits	Fails open	No current will travel to the crane control circuitry. Crane will not operate. Emergency drum band brake will engage. Delay in operations.	No effect.	3
			Fails short	Unlimited current will travel through the transformer and open fuse F1. No power will reach the crane control circuitry. Emergency drum band brake will engage. Delay in operations.	No effect.	3
F1	Fuse (Sheet 3-H7)	Provides electrical overload protection for the secondary winding of CT4, the control circuitry transformer	Premature operation	No current will travel to the control circuitry. Crane will not operate. Emergency drum band brake will engage. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Failure to operate	No current overload protection for crane control circuitry. Damage to electrical conductors. Upstream circuit breaker on transformer primary should trip to remove power from control circuitry. Emergency drum band brake will engage. Delay in operations.	No effect.	3
F2/F3	Fuse (Sheet 5 -C7)	Provides electrical overload protection for the hoist brake coil (HBC)	Premature operation	No current will travel to the hoist brake coil. Hoist will not operate. Delay in operations.	No effect.	3
			Failure to operate	No current overload protection of the hoist brake coil. Damage to electrical conductors. Delay in operations.	No effect.	3
F4/F5	Fuse (Sheet 5 -B6)	Provides electrical overload protection for the hoist pony motor clutch coil transformer (CT1)	Premature operation	No current will travel to the hoist pony motor clutch coil transformer. Hoist will not operate in slow speed. Motor holding brake will remain released. The mechanical load brake will control, stop and hold the load.	No effect.	3
			Failure to operate	No current overload protection of the hoist pony motor clutch coil transformer. Damage to electrical conductors. Delay in operations.	No effect.	3

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Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
F6	Fuse (Sheet 5-A6)	Provides electrical overload protection for the hoist pony motor clutch rectifier (PS1) and coil (HCC)	Premature operation	No current will travel to the hoist pony motor clutch rectifier or coil. Hoist will not operate in slow speed. Motor holding brake will remain released. The mechanical load brake will control, stop and hold the load.	No effect.	3
			Failure to operate	No current overload protection of the hoist pony motor clutch rectifier or coil. Damage to electrical conductors. Delay in operations.	No effect.	3
F7/F8	Fuse (Sheet 5-F4)	Provides electrical overload protection for the trolley brake coil (TB1)	Premature operation	No current will travel to the trolley brake coil. Trolley will not operate. Delay in operations.	No effect.	3
			Failure to operate	No current overload protection of the trolley brake coil. Damage to electrical conductors. Delay in operations.	No effect.	3
F9/F10	Fuse (Sheet 5-F2)	Provides electrical overload protection for trolley pony motor clutch coil transformer (CT2)	Premature operation	No current will travel to the trolley pony motor clutch coil transformer. Trolley will not operate. Delay in operations.	No effect.	3
			Failure to operate	No current overload protection of the trolley pony motor clutch coil transformer. Damage to electrical conductors. Delay in operations.	No effect.	3

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F11	Fuse (Sheet 5 -F2)	Provides electrical overload protection for the trolley pony motor clutch rectifier (PS2) and coil (TCC)	Premature operation	No current will travel to the trolley pony motor clutch rectifier or coil. Trolley will not operate in slow speed. Delay in operations.	No effect.	3
			Failure to operate	No current overload protection of the trolley pony motor clutch rectifier or coil. Damage to electrical conductors. Delay in operations.	No effect.	3
F12/F13	Fuse (Sheet 5 -A4)	Provides electrical overload protection for bridge pony motor clutch coil transformer (CT3)	Premature operation	No current will travel to the bridge pony motor clutch coil transformer. Bridge will not operate in slow speed. Delay in operations.	No effect.	3
			Failure to operate	No current overload protection of the bridge pony motor clutch coil transformer. Damage to electrical conductors. Delay in operations.	No effect.	3
F14	Fuse (Sheet 5 -A4)	Provides electrical overload protection for the bridge pony motor #1 clutch rectifier (PS3) and clutch coil #1 (BCC1)	Premature operation	No current will travel to the bridge pony motor #1 clutch rectifier or coil. Bridge will not operate in slow speed. Delay in operations.	No effect.	3
			Failure to operate	No current overload protection of the bridge pony motor #1 clutch rectifier or coil. Damage to electrical conductors. Delay in operations.	No effect.	3

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Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
F15/F16	Fuse (Sheet 5 -C4)	Provides electrical overload protection for the bridge brake coil #1 (BB1) and #2 (BB2) and oil pump motors.	Premature operation	No current will travel to the bridge brake coils or oil motor pumps. Bridge will not operate. Delay in operations.	No effect.	3
			Failure to operate	No current overload protection of the bridge brake coils and oil pump motors. Damage to electrical conductors. Delay in operations.	No effect.	3
F17	Fuse (Sheet 5 -A3)	Provides electrical overload protection for the bridge pony motor #2 clutch rectifier (PS4) and clutch coil #2 (BCC2)	Premature operation	No current will travel to the bridge pony motor #2 clutch rectifier or coil. Bridge will not operate in slow speed. Delay in operations.	No effect.	3
			Fails to operate	No current overload protection of the bridge clutch coil #2 and oil pump motors. Damage to electrical conductors. Delay in operations.	No effect.	3
HBC	Hoist brake coil (Sheet 5 -C6)	Provides releasing force for the hoist motor brake brakes	Fails open	Hoist will not operate. Brake will remain set. Delay in operations.	No effect.	3
			Fails short	Hoist holding brake will be released. The mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
TB1	Trolley brake coil (Sheet 5-G3)	Provides releasing force for the trolley motor brakes	Fails open	Trolley will not operate. Brake will remain set. Delay in operations.	No effect.	3
			Fails short	Trolley will not operate. Fuse F7 or F8 will protect coil circuitry. Delay in operations.	No effect.	3
BB1	Bridge brake coil #1 (Sheet 5-C3)	Provides releasing force for the mechanically set bridge end truck motor #1 brake.	Fails open	Bridge end truck #1 will not operate. Brake #1 will remain set. Bridge end truck #2 will continue to move bridge, but will eventually the bridge will skew and stall the motor. Delay in operations.	No effect.	3
			Fails short	Bridge end truck #1 will not operate. Fuse F15 or F16 will protect coil circuitry. Bridge end truck #2 will continue to move bridge, but will eventually the bridge will skew and stall the motor. Delay in operations.	No effect.	3
BB2	Bridge brake coil #2 (Sheet 5-C2)	Provides releasing force for the mechanically set bridge end truck motor #2 brake.	Fails open	Bridge end truck #2 will not operate. Brake #2 will remain set. Bridge end truck #1 will continue to move bridge, but will eventually the bridge will skew and stall the motor. Delay in operations.	No effect.	3
			Fails short	Bridge end truck #2 will not operate. Fuse F15 or F16 will protect coil circuitry. Bridge end truck #1 will continue to move bridge, but will eventually the bridge will skew and stall the motor. Delay in operations.	No effect.	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
HCC	Hoist pony motor clutch coil (Sheet 5-B5)	Provides clutch engagement for power transfer from pony motor	Fails open	Clutch does not engage. The mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3
			Fails short	Clutch does not disengage. The hoist main motor could possibly over speed the hoist pony motor and cause damage to internal components of the hoist pony motor reduction gear. Fuse F6 will open. Delay in operations.	No effect.	3
TCC	Trolley pony motor clutch coil (Sheet 5-F1)	Provide clutch engagement for power transfer from the pony motor	Fails open	Clutch does not engage. Trolley will not operate in slow speed. Delay in operations.	No effect.	3
			Fails short	Clutch does not disengage. The trolley main motor could possibly over speed the trolley pony motor and cause damage to internal components of the pony motor & reducer. Fuse F11 will open. Delay in operations.	No effect.	3
BCC1	Bridge clutch coil #1 (pony motor)	Provides clutch engagement for power transfer from pony motor #1	Fails open	Clutch does not engage. Bridge will not operate in slow speed. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
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			Fails short	Clutch does not disengage. The bridge main motor #1 could possibly over speed the bridge pony motor #1 and cause damage to internal components of the pony motor #1. Fuse F14 will open. Delay in operations.	No effect.	3
BCC2	Bridge clutch coil #2 (pony motor)	Provides clutch engagement for power transfer from pony motor #2	Fails open	Clutch does not engage. Bridge will not operate in slow speed. Delay in operations.	No effect.	3
			Fails short	Clutch does not disengage. The bridge main motor #2 could possibly over speed the bridge pony motor #2 and cause damage to internal components of the pony motor #2. Fuse F17 will open. Delay in operations.	No effect.	3
PS1	Rectifier assembly (Sheet 5 -A6)	Converts 120V AC to DC voltage for operation of the hoist pony motor clutch assembly (HCC)	Fails open	Hoist will not operate in slow speed. The mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3
			Fails short	Too much current will travel through the rectifier and fuse F6 will open. Hoist will not operate in slow speed. The mechanical load brake will control, stop and hold the load. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
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PS2	Rectifier assembly (Sheet 5 -E1)	Converts 120V AC to DC voltage for operation of the trolley pony motor clutch assembly (TCC)	Fails open	Trolley will not operate in slow speed. Delay in operations.	No effect.	3
			Fails short	Too much current will travel through the rectifier and fuse F11 will open. Trolley will not operate in slow speed. Delay in operations.	No effect.	3
PS3	Rectifier assembly (Sheet 5 -A4)	Converts 120V AC to 120V DC for operation of the bridge end truck pony motor #1 clutch assembly (BCC1)	Fails open	Bridge will not operate. Delay in operations.	No effect.	3
			Fails short	Too much current will travel through the rectifier and fuse F14 will open. Bridge will not operate. Delay in operations.	No effect.	3
PS4	Rectifier assembly (Sheet 5 -A3)	Converts 120V AC to 120V DC for operation of the bridge end truck pony motor #1 clutch assembly (BCC2)	Fails open	Bridge will not operate. Delay in operations.	No effect.	3
			Fails short	Too much current will travel through the rectifier and fuse F17 will open. Bridge will not operate. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
HM	Thermal overload switch (Sheet 5-D6)	Interrupts control voltage source for the hoist main motor	Fails open	Hoist main motor will not operate. Delay in operations.	No effect	3
			Fails closed	Electrical overload protection lost to hoist main motor. Damage to electrical conductors. Heat sensor for hoist main motor will provide motor protection. Delay in operations.	No effect	3
HP	Thermal overload switch (5-C6)	Interrupts control voltage source for the hoist pony motor	Fails open	Hoist pony motor will not operate. Delay in operations.	No effect	3
			Fails closed	Electrical overload protection lost to hoist main motor. Damage to electrical conductors. Heat sensor for hoist main motor will provide motor protection. Delay in operations.	No effect	3
TM	Thermal overload switch (Sheet 5-G3)	Interrupts control voltage source for the trolley main motor	Fails open	Trolley main motor will not operate. Delay in operations.	No effect	3
			Fails closed	Electrical overload protection lost to trolley main motor. Damage to electrical conductors. Heat sensor for trolley main motor will provide motor protection. Delay in operations.	No effect	3

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TP	Thermal overload switch (Sheet 5-F3)	Interrupts control voltage source for the trolley pony motor	Fails open	Trolley pony motor will not operate. Delay in operations.	No effect	3
			Fails short	Electrical overload protection lost to trolley main motor. Damage to electrical conductors. Heat sensor for trolley main motor will provide motor protection. Delay in operations.	No effect	3
BM	Thermal overload switch (Sheet 5-D3)	Interrupts control voltage source for the bridge main motors	Fails open	Bridge main motors will not operate. Delay in operations.	No effect	3
			Fails short	Electrical overload protection lost to bridge main motors. Damage to electrical conductors. Heat sensor for bridge main motors will provide motor protection. Delay in operations.	No effect	3
BP	Thermal overload switch (Sheet 5-C3)	Interrupts control voltage to the two bridge pony motors	Fails open	Bridge pony motors will not operate. Delay in operations.	No effect	3
			Fails short	Electrical overload protection lost to bridge pony motors. Damage to electrical conductors. Heat sensor for bridge pony motors will provide motor protection. Delay in operations.	No effect	3

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TCT Reuland TC Control #35-648	TC Soft Start Control (Sheet 5-G3)	Controls the applied power (starting torque and acceleration) to the trolley main motor	Inoperative	Trolley will not operate. Delay in operations.	No effect	3
			Fails to control rate of motor acceleration	Trolley will accelerate at a rate faster than at the gradual rate of normal operation. Delay in operations.	No effect	3
			Fails to conduct all three phases of electrical power to motor	Motor may not start or will be noisy and lack power during acceleration. Delay in operations.	No effect	3
TCB Reuland TC Control #55-848	TC Soft Start Control (Sheet 5-D3)	Controls the applied power (starting torque and acceleration) to the trolley main motor	Inoperative	Bridge end trucks will not operate. Delay in operations.	No effect	3
			Fails to control rate of motor acceleration	Bridge will accelerate at a rate faster than at the gradual rate of normal operation. Delay in operations.	No effect	3
			Fails to conduct all three phases of electrical power to motor	Motor may not start or will be noisy and lack power during acceleration. Delay in operations.	No effect	3
SW1	Stop pushbutton switch (Sheet 3-G7)	Provides circuitry for de-energizing the crane's control circuitry	Fails open	All crane systems are stopped, all motors are stopped and all brakes set. Delay in operations.	No effect	3

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			Fails closed	Crane systems will remain energized. All control functions will appear normal. Delay in operations.	No effect	3
SW2	Start push button switch (Sheet 3-G7)		Fails open	All crane systems are stopped, all motors are stopped and all brakes set. Delay in operations.	No effect	3
			Fails closed	Crane systems will remain energized. All control functions will appear normal. Delay in operations.	No effect	3
SW3	Emergency stop push button switches (Sheet 3-G7)	Safety devices. Main push button provides circuitry for de-energizing the main circuit breaker (CB1) from the cab.	Fails open	Main circuit breaker (CB1) will not trip. Stop switch must be manually operated to cut power. Delay in operations.	No effect	3
			Fails closed	Main circuit breaker (CB1) will trip and crane will be inoperative. Delay in operations.	No effect	3
SW4	Hoist high speed switch (Sheet 3-F7)	Fail-safe spring return to neutral type switch that provides circuitry for hoisting or lowering operations of the hoist at high speeds.	Fails open	Hoist will not operate. Delay in operations.	No effect	3

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			a. Fails closed b. Welded contacts c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Hoist may continue to move unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
SW5	Hoist low speed switch (Sheet 3 -E7)	Fail-safe spring return to neutral type switch that provides circuitry for hoisting and lowering operations of the hoist at low speeds.	Fails open	Hoist will not operate. Delay in operations.	No effect	3
			a. Fails closed b. Welded contacts c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Hoist may continue to move unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
SW6	Trolley control switch (Sheet 3 -C7)	Fail-safe spring return to neutral type switch that provides circuitry for trolley operations.	Fails open	Trolley will not operate. Delay in operations.	No effect	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
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			a. Fails closed b. Welded contacts c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Trolley may continue to move unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
SW7	Trolley speed selector switch (Sheet 3-A7)	Provides circuitry for selecting operation of the trolley at slow or high speed.	Fails closed in inch mode	Trolley will only operate at slow speeds. Delay in operations.	No effect	3
			Fails closed in high speed mode	Trolley will only operate at high speeds. Operator must use slow speed within 3 feet of any structure. Trolley is unable to be operated in slow speed. Delay in operations.	No effect	3
SW8	Bridge control switch (Sheet 3-H4)	Fail-safe spring return to neutral type switch that provides circuitry for bridge operations.	Fails open	Bridge will not operate. Delay in operations.	No effect	3

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			a. Fails closed b. Welded contacts c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Bridge may continue to move unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
SW9	Bridge speed selector switch (Sheet 3-F3)	Provides circuitry for selecting operation of the bridge at slow or high speed.	Fails closed in inch mode	Bridge will only operate at slow speeds. Delay in operations.	No effect	3
			Fails closed in high speed mode	Bridge will only operate at high speeds. Operator must use slow speed within 3 feet of any structure. Bridge is unable to be operated in slow speed. Delay in operations.	No effect	3
SW10, SW11, SW12, SW13	Control door interlock switch (Sheet 3-G/H5)		Fails open	Crane will not operate. Delay in operations.	No effect.	3
			Fails closed	Crane will operate, but no indication will be given if a control cabinet is opened.	See Hazards Analysis.	3

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SW15	Emergency brake set relay reset (Sheet 3-G6)	Resets the emergency brake set relay coil (EBSR) to stay contacted in order to release the emergency brake (Emergency drum band brake)	Fails open	The hydraulic valve solenoid coil (SV-1) and the emergency brake set relay coil will not energize (EBSR). Crane will not start. Delay in operations.	No effect	3
			Fails closed	SV-1 and EBSR will be energized, which closes the dump valve to the hydraulic fluid reservoir. When the dump valve is closed, pressure is allowed into the piston and the brakes are released. If an overspeed occurs, LS-1 will open and cut power to crane, causing the dump valve to open, releasing fluid from the brakes, setting the brakes. Delay in operations.	No effect.	3
PPR	Phase reverse relay (Sheet 3-G8)	Provides power to crane only if the wires from power source are wired correctly	Fails open	No power to crane. Delay in operations.	No effect.	3
			Fails closed	Crane will operate normally as long as there is no reverse in phase. No protection against phase reversal.	No effect.	3
MC	Control relay (Sheet 3-G5)	Provides circuitry for energizing the crane controls.	Fails deactivated	Crane will not operate. Delay in operations.	No effect.	3

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			Fails activated	Power will remain available for crane control circuits. All systems will function normally. CB1 and CB2 can be used to shut down the crane.	No effect.	3
LS-1	Limit switch (Sheet 3-G8)	Hoist drum rotary overspeed limit switch (optical encoder); opens at 8.8RPM	Fails open	SV-1 and EBSR will not be energized. Crane will not operate. Delay in operations.	No effect.	3
			a. Fails closed b. Overspeed circuitry fails c. N/A d. Abnormal hoist motion e. N/A f. Immediate g. N/A	SV-1 and EBSR will remain energized. Emergency drum band brake will not engage if an overspeed occurs. Load will continue to drop.	No effect. Overspeed limit switch will be an emergency drum band brake failure cause. See emergency drum band brake.	3
LS-2	Hoist shut down limit switch (Sheet 3-G8)	Mounted on emergency brake; shuts down hoist	Fails open	Crane will not operate. Delay in operations.	No effect.	3
			Fails closed, brake set	If the switch fails closed when the brake is set, power will still be available to the crane. However, since the brake is set, the hoist cannot move.	No effect.	3

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			Fails closed, brake released	If the switch fails closed when the brake is released, hoist could possibly run, but the motor would stall and trip motor overloads, or drive thru and burn up the emergency brake. The holding brake or the load brake will hold the load.	No effect.	3
LS-3 Euclid 2130-4	Weighted limit switch (Sheet 3-F6)	Safety device that limits hoist upward travel during high speed and inching operations.	Fails open	Hoist will not operate in up mode. Delay in operations.	No effect	3
			Fails closed	Hoist upward travel backup protection is lost. Geared limit switch (LS-4a), which is before weighted limit switch (LS-3) will stop hoist. Motor overloads will shut down hoist if both limit switches fail and the hoist "two-blocks". Delay in operations.	No effect	3
LS-4a GE CR115E	Geared limit switch (Sheet 3-F6)	Safety device that limits hoist upward travel with the hoist main motor.	Fails open	Hoist will not operate in up mode. Delay in operations.	No effect	3
			Fails closed	Hoist upward limit control with the hoist main motor is lost. Weighted limit switch (LS-3) is the back up control and will stop the hoist. Motor overloads will shut down hoist if both limit switches fail and the hoist two-blocks. Delay in operations.	No effect	3

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LS-4b GE CR115E	Geared limit switch (Sheet 3-F6)	Safety device that limits hoist downward travel with the hoist main motor.	Fails open	Hoist will not operate in down mode. Delay in operations.	No effect	3
			Fails closed	Hoist downward limit control with the hoist main motor is lost. Delay in operations.	No effect	3
LS-4c GE CR115E	Geared limit switch (Sheet 3-D6)	Safety device that limits hoist upward travel with the hoist pony motor.	Fails open	Hoist will not operate in up mode. Delay in operations.	No effect	3
			Fails closed	Hoist upward limit control with the hoist pony motor is lost. Weighted limit switch (LS-3) is the back up control and will stop the hoist. Motor overloads will shut down hoist if both limit switches fail and the hoist two-blocks. Delay in operations.	No effect	3
LS-4d GE CR115E	Geared limit switch (Sheet 3-D6)	Safety device that limits hoist downward travel with the hoist pony motor.	Fails open	Hoist will not operate in down mode. Delay in operations.	No effect	3
			Fails closed	Hoist downward limit control with the hoist pony motor is lost. Delay in operations.	No effect	3
LS-5	Trolley forward limit switch (Sheet 3-B6)	Safety device that limits trolley forward travel.	Fails open	Trolley will not move forward. Delay in operations.	No effect	3

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			Fails closed	Trolley limit control during forward travel is lost. Operator can control maximum trolley travel by implementing the observer warnings. Delay in operations. Loss of safety device; hard stop will stop trolley.	No effect	3
LS-6	Trolley reverse limit switch (Sheet 3-B6)	Safety device that limits trolley reverse travel.	Fails open	Trolley will not move in reverse. Delay in operations.	No effect	3
			Fails closed	Trolley limit control during reverse travel is lost. Operator can control maximum trolley travel by implementing the observer warnings. Delay in operations. Loss of safety device; hard stop will stop trolley.	No effect	3
LS-7	Trolley slow down limit switch (Sheet 3-A6)	Speed limiting device that slow trolley speed at 4 feet from end of travel.	Fails open	Trolley will only operate at slower speed. Delay in operations.	No effect	3
			Fails closed	Trolley will not slow at required distance. Final stop switch will de-energize trolley motor. Delay in operations.	No effect	3
LS-8	Bridge right truck limit switch (Sheet 3-G2)	Safety device that controls the bridge right truck travel.	Fails open	Bridge right truck will not drive. Delay in operations.	No effect	3

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			Fails closed	Bridge right truck limit of travel is lost. Operator can control maximum bridge travel by implementing the observer warnings. Delay in operations. Loss of safety device; hard stop will stop bridge.	No effect	3
LS-9	Bridge left truck limit switch (Sheet 3-G2)	Safety device that controls the bridge left truck travel.	Fails open	Bridge left truck will not drive. Delay in operations.	No effect	3
			Fails closed	Bridge left truck limit of travel is lost. Operator can control maximum bridge travel by implementing the observer warnings. Delay in operations. Loss of safety device; hard stop will stop bridge.	No effect	3
LS-10/LS-11	Bridge slow down limit switch (Sheet 3-F2)	Speed limiting device that slows bridge speed at 4 feet from end of travel.	Fails open	Bridge will only operate at slower speed. Delay in operations.	No effect	3
			Switch fails closed	Bridge will not slow at required distance. Final stop switch will de-energize trolley motor. Delay in operations.	No effect	3

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TDR-1	Time delay relay for the hoist main motor (Sheet 3-E5)	Applies the required time delay of the hoist main motor during fast mode of operation.	Coil fails open/short	Hoist main motor will not be energized and the brake will not release. The load will not move.	No effect	3
			Switch fails open	Hoist main motor will only operate in slow mode. Delay in operations.	No effect	3
			Switch fails closed	The hoist main motor will remain in fast mode. Slow mode will be inoperative. Delay in operations.	No effect	3
TDR-2	Time delay relay for the hoist pony motor (Sheet 3-C5)	Applies the required time delay of the hoist pony motor during fast mode of operation.	Coil fails open/short	Hoist pony motor will not be energized and the brake will not release. The load will not move.	No effect	3
			Switch fails open	Hoist pony motor will only operate in slow mode. Delay in operations.	No effect	3
			Switch fails closed	The hoist pony motor will remain in fast mode. Slow mode will be inoperative. Delay in operations.	No effect	3
TDR-3	Time delay relay for the trolley main motor (Sheet 3-A5)	Applies the required time delay of the trolley main motor during fast mode of operation.	Coil fails open/short	Trolley main motor will not be energized and the brake will not release. The load will not move.	No effect	3

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			Switch fails open	Trolley main motor will only operate in slow mode. Delay in operations.	No effect	3
			Switch fails closed	The trolley main motor will remain in fast mode. Slow mode will be inoperative. Delay in operations.	No effect	3
TDR-4	Time delay relay for the bridge main motor (Sheet 3-F2)	Applies the required time delay of the bridge main motor during fast mode of operation.	Coil fails open/short	Bridge main motor will not be energized and the brake will not release. The load will not move.	No effect	3
			Switch fails open	Bridge main motor will only operate in slow mode. Delay in operations.	No effect	3
			Switch fails closed	The bridge main motor will remain in fast mode. Slow mode will be inoperative. Delay in operations.	No effect	3
TDR-5	Time delay relay for the emergency drum band brake (Sheet 3-	Applies the required time delay for the emergency drum band brake	Fails open	The emergency drum band brake will not release. Crane will not operate. Delay in operations.	No effect.	3
			Fails closed	Emergency brake will not set. Hoist holding brake or hoist load brake will hold the load. Delay in operations.	No effect.	3

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TDR-6	Time delay relay for the clutch on the hoist pony motor (Sheet 3-D5)	Allows the clutch to be energized and the clutch to seat before the motor is energized and the brake is released.	Coil fails open/short	Hoist pony motor will not be energized and the brake will not release. The load will not move.	No effect	3
			Switch fails open	Hoist pony motor will not be energized and the brake will not release. The load will not move.	No effect	3
			Switch fails closed	Load will drift down approximately 1/8-inch (reference PRACA PR PV-6-402509) before it is raised creating a nuisance problem since crane is operated at slow speed when hoisting flight hardware.	No effect	3
HMUP	Hoist main motor control relay coil (Sheet 3-F5)	Provides circuitry for energizing the hoist main motor during up mode operation.	Fails deactivated	Hoist will not operate in the up direction. Delay in operations.	No effect	3
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Hoist will continue to operate in the up direction unless correcting action is taken. Note: Main motor is used greater than 3 feet away from any structure including flight hardware; therefore, there is enough time for correcting action.	No effect. Use of correcting action prevents damage of a vehicle system.	3

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	Hoist main motor control relay contact to the brake relay coil (Sheet 3-E6)	Energizes the brake relay coil (HBR)	Fails open	Hoist holding brake will not energize. Brake will not release. Delay in operations.	No effect	3
			Fails closed	Hoist holding brake will be energized and released normally. The application of the holding brake will be controlled by one of two relays: HMFA or HMSL.	No effect	3
	Hoist main motor control relay contact (Sheet 3-F5)	Contact that prevents activation of hoist main motor control relay coil in the down direction (HMDN)	Fails open	Hoist will not operate in down direction. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW4) to cause a phase-to-phase short and trip circuit breaker (CB3).	No effect	3
	Hoist main motor control relay contact to the hoist main motor slow relay (Sheet 3-E6)	Contact that activates the hoist main motor slow relay.	Fails open	Crane will not operate. Delay in operations.	No effect	3

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			Fails closed	If the contact fails closed, the mechanical interlock will not allow the HMDN contactor to close, even if the crane is switched to lower. Delay in operations.	No effect	3
	Hoist main motor control relay contact to the hoist pony motor (Sheet 3-E8)	Prevents activation of pony motor when main motor is selected.	Fails open	No effect on system performance. Unable to use pony motor.	No effect	3
			Fails closed	No effect on system performance. Contact HMDN (between 252 and 253) will remove power from pony motor circuitry, only when moving the hoist down with the main motor. Delay in operations.	No effect	3
	Hoist main motor directional control relays (Sheet 5-D7)	Three contacts that control the hoist main motor in the up direction	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3
			Fails closed (single contact)	A closed contact will allow the hoist to operate in the up direction normally. If the down direction is selected, a phase-to-phase short will trip circuit breaker CB3.	No effect	3
HMDN	Hoist main motor control relay coil (Sheet 3-F5)	Provides circuitry for energizing the hoist main motor during down mode operation.	Fails deactivated	Hoist will not operate in the down direction. Delay in operations.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Hoist will continue to operate in the down direction unless correcting action is taken. Note: Main motor is used greater than 3 feet away from any structure including flight hardware; therefore, there is enough time for correcting action.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Hoist main motor control relay contact to the brake relay coil (Sheet 3-E6)	Energizes the brake relay coil (HBR)	Fails open	Hoist holding brake will not energize. Brake will not release. Delay in operations.	No effect	3
			Fails closed	Hoist holding brake will be energized and released normally. The application of the holding brake will be controlled by one of two relays: HMFA or HMSL.	No effect	3
	Hoist main motor control relay contact (Sheet 3-F5)	Contact that prevents activation of hoist main motor control relay coil in the up direction (HMUP)	Fails open	Hoist will not operate in the up direction. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW4) to cause a phase-to-phase short and trip a circuit breaker.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Hoist main motor control relay contact to the hoist main motor slow relay (Sheet 3-E6)	Contact that activates the hoist main motor slow relay.	Fails open	Crane will not operate. Delay in operations.	No effect	3
			Fails closed	If the contact fails closed, the mechanical interlock will not allow the HMUP contactor to close, even if the crane is switched to lower. Delay in operations.	No effect	3
	Hoist main motor control relay contact to the hoist pony motor (Sheet 3-E8)	Prevents activation of pony motor when main motor is selected.	Fails open	No effect on system performance. Unable to use pony motor.	No effect	3
			Fails closed	No effect on system performance. Contact HMUP (between 251 and 252) will remove power from pony motor circuitry, only if moving the hoist up with the main motor. Delay in operations.	No effect	3
	Hoist main motor directional control relays (Sheet 5-D7)	Three contacts that control the hoist main motor in the down direction	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails closed (single contact)	A closed contact will allow the hoist to operate in the down direction normally. If the up direction is selected, a phase-to-phase short will trip circuit breaker CB3.	No effect	3
HMSL	Hoist main motor control relay coil (Sheet 3-E5)	Provides circuitry for energizing the hoist main motor in slow speed during operation.	Fails deactivated	Hoist will not operate in the slow speed. Delay in operations.	No effect	3
			Fails activated	Hoist will only operate in the slow speed and function normally. If the fast speed is selected, a phase-to-phase short will result and trip CB3. Delay in operations.	No effect	3
	Hoist main motor control relay contact to the brake relay coil (Sheet 3-E5)	Energizes the brake relay coil (HBR)	Fails open	Hoist holding brake will not energize. Brake will not release. Delay in operations.	No effect	3
			Fails closed	Hoist holding brake will be energized and released normally. The application of the holding brake will be controlled by one of two relays: HMUP or HMDN.	No effect	3
	Hoist main motor speed control relays (Sheet 5-D7)	Three contacts that control the hoist main motor in the slow mode	Fails closed (single contact)	System will function normally in the slow speed. If fast speed is selected, a phase-to-phase short will result and trip circuit breaker CB3.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition. Brake will set.	No effect	3
HMFA	Hoist main motor control relay coil (Sheet 3-E5)	Provides circuitry for energizing the hoist main motor in fast speed during operation.	Fails deactivated	Hoist will not operate in the fast speed. Delay in operations.	No effect	3
			Fails activated	Hoist will only operate in the fast speed. Operator must use slow speed within 3 feet of any structure. Hoist is unable to be operated in slow speed. Delay in operations.	No effect	3
	Hoist main motor control relay contact to the brake relay coil (Sheet 3-E5)	Energizes the brake relay coil (HBR)	Fails open	Hoist holding brake will not energize. Brake will not release. Delay in operations.	No effect	3
			Fails closed	Hoist holding brake will be energized and released normally. The application of the holding brake will be controlled by one of two relays: HMUP or HMDN.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Hoist main motor slow relay contact (Sheet 3-E5)	Prevents activation of slow speed when the hoist main motor is selected.	Fails open	Slow speed is inoperative. Delay in operations.	No effect.	3
			Fails closed	Hoist will only operate in the slow speed. If fast speed is selected, both motors will be energized. The main motor could possibly over speed the pony motor causing damage to internal components. Delay in operations.	No effect.	3
	Hoist main motor speed control relays (Sheet 5-D7)	Three contacts that control the hoist main motor in the fast mode	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition. Brake will set.	No effect	3
			Fails closed (single contact)	System will function normally in the fast speed. If slow speed is selected, a phase-to-phase short will result and trip circuit breaker CB3.	No effect	3
HBR	Hoist brake control coil (Sheet 3-E5)	Energizes the brake coil for the hoist main motor	Fails deactivated	Holding brake will remain set. Delay in operations.	No effect.	3
			Fails activated	Holding brake will remain released. Load brake will hold the load.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Hoist brake contact (Sheet 5-C7)	Energizes the brake solenoid to release the hoist main motor brake	Fails open (single contact)	Hoist brake solenoid will not energize. Brake will not release. Delay in operations.	No effect.	3
			Fails closed (single contact)	If one HBR fails closed, the other HBR contact opens. Requires double failure of both HBR contacts.	No effect.	3
HPUP	Hoist pony motor control relay coil (Sheet 3-D5)	Provides circuitry for energizing the hoist pony motor during up mode operation.	Fails deactivated	Hoist will not operate in the up direction. Delay in operations.	No effect	3
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Hoist will continue to operate in the up direction unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Hoist pony motor control relay contact to the brake relay coil (Sheet 3-E6)	Energizes the brake relay coil (HBR)	Fails open	Hoist holding brake will not energize. Brake will not release. Delay in operations.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails closed	Hoist holding brake will be energized and released normally. The application of the holding brake will be controlled by one of two relays: HPFA or HPSL.	No effect	3
	Hoist pony motor control relay contact (Sheet 3-D5)	Contact that prevents activation of hoist pony motor control relay coil in the down direction (HPDN)	Fails open	Hoist will not operate in down direction. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW5) to cause a phase-to-phase short and trip circuit breaker (CB3).	No effect	3
	Hoist pony motor control relay contact to the hoist main motor slow relay (Sheet 3-D6)	Contact that activates the hoist pony motor slow relay.	Fails open	Crane will not operate. Delay in operations.	No effect	3
			Fails closed	If the contactor fails closed, the mechanical interlock will not allow the HPDN contactor to close, even if the crane is switched to lower. Delay in operations.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Hoist pony motor control relay contact to the hoist main motor (Sheet 3-F8)	Prevents activation of main motor when the pony motor is selected.	Fails open	No effect on system performance. Unable to use main motor.	No effect	3
			Fails closed	No effect on system performance. Contact HPDN (between 202 and 203) will remove power from the main motor circuitry, only when operating the pony motor in the down direction. Delay in operations.	No effect	3
	Hoist pony motor directional control relays (Sheet 5-C7)	Three contactors that control the hoist pony motor in the up direction	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3
			Fails closed (single contact)	A closed contact will allow the hoist to operate in the up direction normally. If the down direction is selected, a phase-to-phase short will trip circuit breaker CB3.	No effect	3
HPDN	Hoist pony motor control relay coil (Sheet 3-D5)	Provides circuitry for energizing the hoist pony motor during down mode operation.	Fails deactivated	Hoist will not operate in the down direction. Delay in operations.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Hoist will continue to operate in the down direction unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Hoist pony motor control relay contact to the brake relay coil (Sheet 3-E6)	Energizes the brake relay coil (HBR)	Fails open	Hoist holding brake will not energize. Brake will not release. Delay in operations.	No effect	3
			Fails closed	Hoist holding brake will be energized and released normally. The application of the holding brake will be controlled by one of two relays: HPFA or HPSL.	No effect	3
	Hoist pony motor control relay contact (Sheet 3-D5)	Contact that prevents activation of hoist pony motor control relay coil in the up direction (HPUP)	Fails open	Hoist will not operate in up direction. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW5) to cause a phase-to-phase short and trip circuit breaker (CB3).	No effect	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Hoist pony motor control relay contact to the hoist main motor slow relay (Sheet 3-D6)	Contact that activates the hoist pony motor slow relay.	Fails open	Crane will not operate. Delay in operations.	No effect	3
			Fails closed	If the contactor fails closed, the mechanical interlock will not allow the HPUP contactor to close, even if the crane is switched to raise. Delay in operations.	No effect	3
	Hoist pony motor control relay contact to the hoist main motor (Sheet 3-F8)	Prevents activation of main motor when the pony motor is selected.	Fails open	No effect on system performance. Unable to use main motor.	No effect	3
			Fails closed	No effect on system performance. Contact HPUP (between 202 and 203) will remove power from the main motor circuitry, only when moving the pony motor in the up direction. Delay in operations.	No effect	3
	Hoist pony motor directional control relays (Sheet 5-B7)	Three contacts that control the hoist pony motor in the up direction	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails closed (single contact)	A closed contact will allow the hoist to operate in the down direction normally. If the up direction is selected, a phase-to-phase short will trip circuit breaker CB3.	No effect	3
HPSL	Hoist pony motor control relay coil (Sheet 3-D5)	Provides circuitry for energizing the hoist pony motor in slow speed during operation.	Fails deactivated	Hoist will not operate in the slow speed. Delay in operations.	No effect	3
			Fails activated	Hoist will only operate in the slow speed and function normally. If the fast speed is selected, a phase-to-phase short will result and trip CB4. Delay in operations.	No effect	3
	Hoist pony motor control relay contact to the brake relay coil (Sheet 3-E5)	Energizes the brake relay coil (HBR)	Fails open	Hoist holding brake will not energize. Brake will not release. Delay in operations.	No effect	3
			Fails closed	Hoist holding brake will be energized and released normally. The application of the holding brake will be controlled by one of two relays: HPUP or HPDN.	No effect	3
	Hoist pony motor speed control relays (Sheet 5-C6)	Three contacts that control the hoist pony motor in the slow mode	Fails closed (single contact)	System will function normally in the slow speed. If fast speed is selected, a phase-to-phase short will result and trip circuit breaker CB3.	No effect	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition. Brake will set.	No effect	3
HPFA	Hoist pony motor control relay coil (Sheet 3-D5)	Provides circuitry for energizing the hoist pony motor in fast speed during operation.	Fails deactivated	Hoist will not operate in the fast speed. Delay in operations.	No effect	3
			Fails activated	Hoist will only operate in the fast speed. Operator must use slow speed within 3 feet of any structure. Hoist is unable to move in slow speed. Delay in operations.	No effect	3
	Hoist pony motor control relay contact to the brake relay coil (Sheet 3-E5)	Energizes the brake relay coil (HBR)	Fails open	Hoist holding brake will not energize. Brake will not release. Delay in operations.	No effect	3
			Fails closed	Hoist holding brake will be energized and released normally. The application of the holding brake will be controlled by one of two relays: HPUP or HPDN.	No effect	3
	Hoist pony motor slow relay contact (Sheet 3-D5)	Prevents activation of slow speed when the hoist pony motor is selected.	Fails open	Slow speed is inoperative. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails closed	Hoist will only operate in the slow speed. If fast speed is selected, both motors will be energized. The main motor could possibly over speed the pony motor causing damage to internal components. Delay in operations.	No effect.	3
	Hoist pony motor speed control relays (Sheet 5-B6)	Three contacts that control the hoist pony motor in the slow mode	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition. Brake will set.	No effect	3
			Fails closed (single contact)	System will function normally in the fast speed. If slow speed is selected, a phase-to-phase short will result and trip circuit breaker CB4.	No effect	3
TMRV	Trolley main motor control relay coil (Sheet 3-B5)	Provides circuitry for energizing the trolley main motor during reverse mode operation.	Fails deactivated	Trolley will not operate in the reverse direction. Delay in operations.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Trolley will continue to operate in the reverse direction unless correcting action is taken. Note: Main motor is used greater than 3 feet away from any structure including flight hardware; therefore, there is enough time for correcting action.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Trolley main motor control relay contact to the brake relay coil (Sheet 3-B6)	Energizes the brake relay coil (TBR)	Fails open	Trolley brake will not energize or release. Delay in operations.	No effect	3
			Fails closed	Trolley brake will be energized and released normally.	No effect	3
	Trolley main motor control relay contact (Sheet 3-C5)	Contact that prevents activation of trolley main motor control relay coil in the forward direction (TMFD)	Fails open	Trolley will not operate in forward direction. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW6) to cause a phase-to-phase short and trip circuit breaker (CB5).	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Trolley main motor control relay contact to the trolley main motor slow relay (Sheet 3-B7)	Contact that activates the trolley motor slow relay.	Fails open	Crane will not operate in reverse direction. Delay in operations.	No effect	3
			Fails closed	System will function normally in the slow speed. If fast speed is selected, a phase-to-phase short will result and trip circuit breaker CB5. Delay in operations.	No effect	3
	Trolley soft start contact (Sheet 3-C6)	Contact that activates the soft start (TCT)	Fails open	If the reverse contact does not close, the trolley main motor will not start. Delay in operations.	No effect.	3
			Fails closed	Trolley main motor will start in reverse direction as normal. If the contact fails closed, the mechanical interlock will not allow the TMFD contactor to close, even if the crane is switched to the forward direction. Delay in operations.	No effect.	3
	Trolley main motor directional control relays (Sheet 5-G4)	Three contacts that control the trolley main motor in the reverse direction	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
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			Fails closed (single contact)	A closed contact will allow the trolley to operate in the reverse direction normally. If the forward direction is selected, a phase-to-phase short will trip circuit breaker CB5.	No effect	3
TMFD	Trolley main motor control relay coil (Sheet 3-C5)	Provides circuitry for energizing the trolley main motor during forward mode operation.	Fails deactivated	Trolley will not operate in the forward direction. Delay in operations.	No effect	3
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Trolley will continue to operate in the forward direction unless correcting action is taken. Note: Main motor is used greater than 3 feet away from any structure including flight hardware; therefore, there is enough time for correcting action.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Trolley main motor control relay contact to the brake relay coil (Sheet 3-B6)	Energizes the brake relay coil (TBR)	Fails open	Trolley brake will not energize or release. Delay in operations.	No effect	3
			Fails closed	Trolley brake will be energized and released normally. Friction will slow the trolley to a stop.	No effect	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Trolley main motor control relay contact (Sheet 3-B5)	Contact that prevents activation of trolley main motor control relay coil in the reverse direction (TMRV)	Fails open	Trolley will not operate in reverse direction. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW6) to cause a phase-to-phase short and trip circuit breaker (CB5).	No effect	3
	Trolley main motor control relay contact to the trolley main motor slow relay (Sheet 3-B7)	Contact that activates the trolley motor slow relay.	Fails open	Crane will not operate in forward direction. Delay in operations.	No effect	3
			Fails closed	System will function normally in the slow speed. If fast speed is selected, a phase-to-phase short will result and trip circuit breaker CB5. Delay in operations.	No effect	3
	Trolley soft start contact (Sheet 3-C6)	Contact that activates the soft start (TCT)	Fails open	If the forward contact does not close, the trolley main motor will not start. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails closed	Trolley main motor will start in forward direction as normal. If the contactor fails closed, the mechanical interlock will not allow the TMRV contactor to close, even if the crane is switched to the reverse direction. Delay in operations.	No effect.	3
	Trolley main motor directional control relays (Sheet 5-D7)	Three contacts that control the trolley main motor in the forward direction	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3
			Fails closed (single contact)	A closed contact will allow the trolley to operate in the forward direction normally. If the reverse direction is selected, a phase-to-phase short will trip circuit breaker CB5.	No effect	3
TMSL	Trolley main motor control relay coil (Sheet 3-B5)	Provides circuitry for energizing the trolley main motor in slow speed during operation.	Fails deactivated	Trolley will not operate in the slow speed. Delay in operations.	No effect	3
			Fails activated	Trolley will only operate in the slow speed & function normally. If the fast speed is selected, a phase-to-phase short will result and trip CB5. Delay in operations.	No effect	3
	Trolley soft start contact (Sheet 3-C6)	Contact that activates the soft start (TCT)	Fails open	If the slow contact does not close, the trolley main motor will not start. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails closed	Trolley main motor will start in slow speed as normal. If the contactor fails closed, the mechanical interlock will not allow the TMFA contactor to close, even if the crane is switched to the fast mode. Delay in operations.	No effect.	3
	Trolley main motor speed control relays (Sheet 5-H2)	Three contacts that control the trolley main motor in the slow mode	Fails closed (single contact)	System will function normally in the slow speed. If fast speed is selected, a phase-to-phase short will result and trip circuit breaker CB5.	No effect	3
			Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition. Brake will set.	No effect	3
TMFA	Trolley main motor control relay coil (Sheet 3-A5)	Provides circuitry for energizing the trolley main motor in fast speed during operation.	Fails deactivated	Trolley will not operate in the fast speed. Delay in operations.	No effect	3
			Fails activated	Trolley will only operate in the fast speed. Operator must use slow speed within 3 feet of any structure. Trolley is unable to move in slow speed. Delay in operations.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Trolley main motor slow relay contactor (Sheet 3-B5)	Prevents activation of slow speed when the trolley main motor is selected.	Fails open	Slow speed is inoperative. Delay in operations.	No effect.	3
			Fails closed	Trolley will only operate in the slow speed. If fast mode is selected, both motors will be energized. The main motor could possibly over speed the pony motor causing damage to internal components. Delay in operations.	No effect.	3
	Trolley soft start contact (Sheet 3-C6)	Contact that activates the soft start (TCT)	Fails open	If the fast contact does not close, the trolley main motor will not start. Delay in operations.	No effect.	3
			Fails closed	Trolley main motor will start in fast speed as normal. If the contactor fails closed, the mechanical interlock will not allow the TMSL contactor to close, even if the crane is switched to the slow mode. Delay in operations.	No effect.	3
	Trolley main motor speed control relays (Sheet 5-D7)	Three contacts that control the trolley main motor in the slow mode	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition. Brake will set.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails closed (single contact)	System will function normally in the fast speed. If slow speed is selected, a phase-to-phase short will result and trip circuit breaker CB5.	No effect	3
TBR	Trolley brake (Sheet 3-B5)	Energizes the trolley brake coil for the spring-loaded brake assembly on the trolley	Fails deactivated	Trolley brake will remain set. Delay in operations.	No effect.	3
			Fails activated	Trolley brake will remain released. Friction will slow the trolley to a stop.	No effect.	3
	Trolley brake contacts (Sheet 5-F3)	Energizes the brake coil to release the trolley brakes	Fails open (single contact)	Trolley brake solenoid will not energize. Brake will not release. Delay in operations.	No effect.	3
			Fails closed (single contact)	If one TBR fails closed, the other TBR contact opens. Requires double failure of both TBR contacts.	No effect.	3
TPRV	Trolley pony motor control relay coil (Sheet 3-B5)	Provides circuitry for energizing the trolley pony motor during reverse mode operation.	Fails deactivated	Trolley will not operate in the reverse direction. Delay in operations.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Trolley will continue to operate in the reverse direction unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Trolley pony motor control relay contact to the brake relay coil (Sheet 3-B6)	Energizes the brake relay coil (TBR)	Fails open	Trolley brake will not energize or release. Delay in operations.	No effect	3
			Fails closed	Trolley brake will be energized and released normally. Friction will slow the trolley to a stop.	No effect	3
	Trolley pony motor control relay contactor (Sheet 3-C5)	Contact that prevents activation of trolley pony motor control relay coil in the forward direction (TPFD)	Fails open	Trolley will not operate in forward direction. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW6) to cause a phase-to-phase short and trip circuit breaker (CB6).	No effect	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Trolley pony motor directional control relays (Sheet 5-F4)	Three contacts that control the trolley pony motor in the reverse direction	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3
			Fails closed (single contact)	A closed contact will allow the trolley to operate in the reverse direction normally. If the forward direction is selected, a phase-to-phase short will trip circuit breaker CB6.	No effect	3
TPFD	Trolley pony motor control relay coil (Sheet 3-C5)	Provides circuitry for energizing the trolley pony motor during forward mode operation.	Fails deactivated	Trolley will not operate in the forward direction. Delay in operations.	No effect	3
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Trolley will continue to in the forward direction unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Trolley pony motor control relay contact to the brake relay coil (Sheet 3-B6)	Energizes the brake relay coil (TBR)	Fails open	Trolley brake will not energize or release. Delay in operations.	No effect	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails closed	Trolley brake will be energized and released normally. Friction will slow the trolley to a stop.	No effect	3
	Trolley pony motor control relay contact (Sheet 3-B5)	Contact that prevents activation of trolley pony motor control relay coil in the reverse direction (TPRV)	Fails open	Trolley will not operate in reverse direction. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW6) to cause a phase-to-phase short and trip circuit breaker (CB6).	No effect	3
	Trolley pony motor directional control relays (Sheet 5-F4)	Three contacts that control the trolley pony motor in the forward direction	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3
			Fails closed (single contact)	A closed contact will allow the trolley to operate in the forward direction normally. If the reverse direction is selected, a phase-to-phase short will trip circuit breaker CB6.	No effect	3
TST	Control relay, 120V (Sheet 3-A5)	Controls circuitry for high and low speed ranges of the trolley	Fails deactivated	Trolley will only operate using the pony motor. Delay in operations.	No effect.	3

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Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Fails activated	Trolley will only move by using trolley main motor. TST contacts remain in energized state and prevent pony motor operation. Operator will notice speed difference and stop trolley movement with master switch. Delay in operations.	No effect.	3
	Control relay contacts (Sheet 3-C6)	Controls the selection of the main and pony motors in the forward direction	Contact between 303 and 304 fails open	Loss of the trolley main motor in the forward direction.	No effect.	3
			Contact between 303 and 304 fails closed	Trolley main motor and pony motor will both be selected in the forward direction. Main motor would over speed the pony motor and possibly cause damage to internal components.	No effect.	3
			Contact between 303 and 306 fails open	Loss of the trolley pony motor in the forward direction.	No effect.	3
			Contact between 303 and 306 fails closed	Trolley main motor and pony motor will both be selected in the forward direction. Main motor would over speed the pony motor and possibly cause damage to internal components.	No effect.	3
	Control relay contacts (Sheet 3-B6)	Controls the selection of the main and pony motors in the reverse direction	Contact between 312 and 313 fails open	Loss of the trolley main motor in the reverse direction.	No effect.	3

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Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Contact between 312 and 313 fails closed	Trolley main motor and pony motor will both be selected in the reverse direction. Main motor would over speed the pony motor and possibly cause damage to internal components.	No effect.	3
			Contact between 312 and 309 fails open	Loss of the trolley pony motor in the reverse direction.	No effect.	3
			Contact between 312 and 309 fails closed	Trolley main motor and pony motor will both be selected in the reverse direction. Main motor would over speed the pony motor and possibly cause damage to internal components.	No effect.	3
BMR	Bridge main motor control relay coil (Sheet 3-G1)	Provides circuitry for energizing the bridge main motor during operation to the right	Fails deactivated	Bridge will not operate to the right. Delay in operations.	No effect	3
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Bridge will continue to operate to the right unless correcting action is taken. Note: Main motor is used greater than 3 feet away from any structure including flight hardware; therefore, there is enough time for correcting action.	No effect. Use of correcting action prevents damage of a vehicle system.	3

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	Bridge main motor control relay contact to the brake relay coil (Sheet 3-G2)	Energizes the brake relay coil (BBR)	Fails open	Bridge brake will not energize or release. Delay in operations.	No effect	3
			Fails closed	Bridge brake will be energized and released normally. Friction will slow the bridge to a stop.	No effect	3
	Bridge main motor control relay contact (Sheet 3-G2)	Contact that prevents activation of bridge main motor control relay coil to the left (BML)	Fails open	Bridge will not operate to the left. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW8) to cause a phase-to-phase short and trip circuit breaker (CB7).	No effect	3
	Bridge main motor control relay contact to the bridge main motor slow relay (Sheet 3-F3)	Contact that activates the bridge motor slow relay.	Fails open	Crane will not operate with the bridge moving to the right. Delay in operations.	No effect	3

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			Fails closed	Slow speed would remain selected even when the bridge control switch is not being operated. Selecting a fast speed with the joystick could cause an instantaneously phase-to-phase fault and circuit breaker CB7 would trip. Delay in operations.	No effect	3
	Bridge soft start contact (Sheet 3 -H2)	Contact that activates the soft start (TCT)	Fails open	If the BMR contact does not close, the bridge motor will not start. Delay in operations.	No effect.	3
			Fails closed	Bridge motor will start to the right as normal. If the contact fails closed, the mechanical interlock will not allow the BML contactor to close, even if the crane is switched to the BML. Delay in operations.	No effect.	3
	Bridge main motor directional control relays (Sheet 5 -H2)	Three contact that control the bridge main motor to the right	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3
			Fails closed (single contact)	A closed contact will allow the bridge to operate to the right normally. If BML is selected, a phase-to-phase short will trip circuit breaker CB7 .	No effect	3
BML	Bridge main motor control relay coil (Sheet 3 -G1)	Provides circuitry for energizing the bridge main motor during operation to the left	Fails deactivated	Bridge will not operate to the left. Delay in operations.	No effect	3

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System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Bridge will continue to operate to the left unless correcting action is taken. Note: Main motor is used greater than 3 feet away from any structure including flight hardware; therefore, there is enough time for correcting action.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Bridge main motor control relay contact to the brake relay coil (Sheet 3-G2)	Energizes the brake relay coil (BBR)	Fails open	Bridge brake will not energize or release. Delay in operations.	No effect	3
			Fails closed	Bridge brake will be energized and released normally. Friction will slow the bridge to a stop.	No effect	3
	Bridge main motor control relay contact (Sheet 3-G2)	Contact that prevents activation of bridge main motor control relay coil to the right (BMR)	Fails open	Bridge will not operate to the right. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW8) to cause a phase-to-phase short and trip circuit breaker (CB7).	No effect	3

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	Bridge main motor control relay contact to the bridge main motor slow relay (Sheet 3-F3)	Contact that activates the bridge motor slow relay.	Fails open	Crane will not operate to the left. Delay in operations.	No effect	3
			Fails closed	If the contactor fails closed, the mechanical interlock will not allow the BMR contactor to close, even if the crane is switched to go to the right. Delay in operations.	No effect	3
	Bridge soft start contact (Sheet 3-H2)	Contact that activates the soft start (TCT)	Fails open	Slow speed would remain selected even when the bridge control switch is not being operated. Selecting a fast speed with the joystick could cause an instantaneous phase-to-phase fault and circuit breaker CB7 would trip. Delay in operations.	No effect.	3
			Fails closed	Bridge motor will start to the left as normal. If the contact fails closed, the mechanical interlock will not allow the BMR contactor to close, even if the crane is switched to the BMR. Delay in operations.	No effect.	3
	Bridge main motor directional control relays (Sheet 5-H2)	Three contacts that control the bridge main motor to the left	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3

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			Fails closed (single contact)	A closed contact will allow the bridge to operate to the left normally. If BMR is selected, a phase-to-phase short will trip circuit breaker CB7.	No effect	3
BBR	Bridge brake (Sheet 3-G1)	Energizes the bridge brake coil for the spring-loaded brake assembly	Fails deactivated	Bridge brake will remain set. Delay in operations.	No effect.	3
			Fails activated	Bridge brake will remain released. Friction will slow the bridge to a stop.	No effect.	3
	Bridge brake contacts (Sheet 5-C7)	Energizes the brake coil to release the bridge brakes	Fails open (single contact)	Bridge brake solenoid will not energize. Brake will not release. Delay in operations.	No effect.	3
			Fails closed (single contact)	If one BBR fails closed, the other BBR contact opens. Requires double failure of both BBR contacts.	No effect.	3
BMS	Bridge main motor control relay coil (Sheet 3-F1)	Provides circuitry for energizing the bridge main motor in slow speed during operation.	Fails deactivated	Bridge will not operate in the slow speed. Delay in operations.	No effect	3
			Fails activated	Bridge will only operate in the slow speed & function normally. If the fast speed is selected, a phase-to-phase short will result and trip CB7. Delay in operations.	No effect	3

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	Bridge soft start contact (Sheet 3-H2)	Contact that activates the soft start (TCT)	Fails open	If the slow contact does not close, the bridge main motor will not start. Delay in operations.	No effect.	3
			Fails closed	Bridge main motor will start in slow speed as normal. If the contactor fails closed, the mechanical interlock will not allow the BMF contactor to close, even if the crane is switched to the fast mode. Delay in operations.	No effect.	3
	Bridge main motor speed control relays (Sheet 5-D2)	Three contacts that control the bridge main motor in the slow mode	Fails closed (single contact)	System will function normally in the slow speed. If fast speed is selected, a phase-to-phase short will result and trip circuit breaker CB7.	No effect	3
			Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition. Brake will set.	No effect	3
BMF	Bridge main motor control relay coil (Sheet 3-F1)	Provides circuitry for energizing the bridge main motor in fast speed during operation.	Fails deactivated	Bridge will not operate in the fast speed. Delay in operations.	No effect	3
			Fails activated	Bridge will only operate in the fast speed. Operator must use slow speed within 3 feet of any structure. Hoist is unable to move in slow speed. Delay in operations.	No effect	3

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Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Bridge main motor slow relay contact (Sheet 3-F2)	Prevents activation of slow speed when the bridge main motor is selected.	Fails open	Slow speed is inoperative. Delay in operations.	No effect.	3
			Fails closed	Bridge will only operate in the slow speed. If fast mode is selected, both motors will be energized. The main motor could possibly over speed the pony motor causing damage to internal components. Delay in operations.	No effect.	3
	Bridge soft start contact (Sheet 3-H2)	Contact that activates the soft start (TCT)	Fails open	If the fast contact does not close, the bridge main motor will not start. Delay in operations.	No effect.	3
			Fails closed	Bridge main motor will start in fast speed as normal. If the contactor fails closed, the mechanical interlock will not allow the BMS contactor to close, even if the crane is switched to the slow mode. Delay in operations.	No effect.	3
	Bridge main motor speed control relays (Sheet 5-D2)	Three contacts that control the bridge main motor in the slow mode	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition. Brake will set.	No effect	3

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			Fails closed (single contact)	No effect. No complete circuit. System will function normally in the fast speed. If slow speed is selected, a phase-to-phase short will result and trip circuit breaker CB7.	No effect	3
BPR	Bridge pony motor control relay coil (Sheet 3-G1)	Provides circuitry for energizing the bridge pony motor during operation to the right	Fails deactivated	Bridge will not operate to the right. Delay in operations.	No effect	3
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Bridge will continue to operate to the right unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Bridge pony motor control relay contact to the brake relay coil (Sheet 3-G2)	Energizes the brake relay coil (BBR)	Fails open	Bridge brake will not energize or release. Delay in operations.	No effect	3
			Fails closed	Bridge brake will be energized and released normally. Friction will slow the bridge to a stop.	No effect	3

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	Bridge pony motor control relay contactor (Sheet 3-G2)	Contact that prevents activation of bridge pony motor control relay coil to the left (BPL)	Fails open	Bridge will not operate to the left. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW8) to cause a phase-to-phase short and trip circuit breaker (CB8).	No effect	3
	Bridge pony motor directional control relays (Sheet 5-H2)	Three contacts that control the bridge pony motor to the right	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3
			Fails closed (single contact)	A closed contact will allow the bridge to operate to the right normally. If BMR is selected, a phase-to-phase short will trip circuit breaker CB8.	No effect	3
BPL	Bridge pony motor control relay coil (Sheet 3-G1)	Provides circuitry for energizing the bridge pony motor during operation to the left	Fails deactivated	Bridge will not operate to the left. Delay in operations.	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			a. Fails activated b. Relay sticks c. N/A d. Visual e. Use of stop switch (SW1) or emergency push button (SW3) f. Seconds g. Seconds	Bridge will continue to operate to the left unless correcting action is taken.	No effect. Use of correcting action prevents damage of a vehicle system.	3
	Bridge pony motor control relay contact to the brake relay coil (Sheet 3-G2)	Energizes the brake relay coil (BBR)	Fails open	Bridge brake will not energize or release. Delay in operations.	No effect	3
			Fails closed	Bridge brake will be energized and released normally. Friction will slow the bridge to a stop.	No effect	3
	Bridge pony motor control relay contact (Sheet 3-G2)	Contact that prevents activation of bridge pony motor control relay coil to the right (BPR)	Fails open	Bridge will not operate to the right. Delay in operations.	No effect	3
			Fails closed	Requires double failure of the main switch (SW8) to cause a phase-to-phase short and trip circuit breaker (CB8).	No effect	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
	Bridge pony motor directional control relays (Sheet 5-H2)	Three contacts that control the bridge pony motor to the left	Fails open (single contact)	Three-phase power would be reduced to single-phase power, effectively reducing the rated output of the motor. The motor may not start under this condition.	No effect	3
			Fails closed (single contact)	A closed contact will allow the bridge to operate to the left normally. If BMR is selected, a phase-to-phase short will trip circuit breaker CB8.	No effect	3
TSB	Control relay, 120V (Sheet 3-F1)	Controls circuitry for high and low speed ranges of the bridge	Fails deactivated	Bridge will only operate using the pony motor. Delay in operations.	No effect.	3
			Fails activated	Bridge will only move by using bridge main motor. TSB contacts remain in energized state and prevent pony motor operation. Operator will notice speed difference and stop bridge movement with master switch. Delay in operations.	No effect.	3
	Control relay contacts (Sheet 3-G2)	Controls the selection of the main and pony motors to the left	Contact between 403 and 404 fails open	Loss of the bridge main motor to the right.	No effect.	3
			Contact between 403 and 404 fails closed	Bridge main motor and pony motor will both be selected to the right. Main motor would over speed the pony motor and possibly cause damage to internal components.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
			Contact between 403 and 406 fails open	Loss of the bridge pony motor to the right.	No effect.	3
			Contact between 403 and 406 fails closed	Bridge main motor and pony motor will both be selected to the right. Main motor would over speed the pony motor and possibly cause damage to internal components.	No effect.	3
	Control relay contacts (Sheet 3-B6)	Controls the selection of the main and pony motors in the reverse direction	Contact between 412 and 413 fails open	Loss of the bridge main motor to the left.	No effect.	3
			Contact between 412 and 413 fails closed	Bridge main motor and pony motor will both be selected to the left. Main motor would over speed the pony motor and possibly cause damage to internal components.	No effect.	3
			Contact between 412 and 409 fails open	Loss of the bridge pony motor to the left.	No effect.	3
			Contact between 412 and 409 fails closed	Bridge main motor and pony motor will both be selected to the right. Main motor would over speed the pony motor and possibly cause damage to internal components.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
H	Horn (Sheet 4)	Safety device that warns operator of motor(s) overheating condition.	Fails deactivated	Audio alarm to operator is lost. Red light indicator will warn operator of problem. Delay in operations.	No effect.	3
			Fails activated	Audio alarm operates continuously. Delay in operations.	No effect.	3
R	Red light (Sheet 4)	Safety device that warns operator of motor(s) overheating condition.	Fails open	Visual alarm to operator is lost. Horn will warn operator of problem. Delay in operations.	No effect.	3
			Fails closed	Visual alarm to operator is lost. Horn will warn operator of problem. Delay in operations.	No effect.	3
TS-H1 – TS-BH, TS-IL – TS3L, TS-5L – TS7L	Motor shutdown sensors (Sheet 4)	Safety device. Heat sensing devices to shut down motor(s).	Fails deactivated	Motor heating sensing and shut down safety is lost. Possible motor damage. This type of failure is not detectable by the crane operator. Delay in operations.	No effect.	3
			Fails activated	Motor(s) shut down. Delay in operations.	No effect.	3
TS-1A – TS-8A	Motor alarm sensors (Sheet 4)	Safety device. Heat sensing devices that actuate alarm system.	Fails deactivated	Operator warning of overheating motor(s) is lost. Motor heat sensors will shut down motors. This type of failure is not detectable by the crane operator. Delay in operations.	No effect.	3

Table 7. FMEA - 30-Ton Bridge Crane - Electrical FMEA						Pages 26 to 99
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379					**Drawing No.:** 79K16771 **Reference:**	
Find No. Part No.	**Part Name**	**Part Function**	**a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe**	**Failure Effect On System Performance**	**Failure Effect On Vehicle Systems And/Or Personnel Safety**	**Crit Cat**
PPR	Phase reversal relay (Sheet 3-G8)	Safety device provides protection for phase reversal and phase loss	Fails closed	Phase loss or reversal will not be identified. Operator will identify during initial movement of crane.	No effect.	3
			Fails open	Crane inoperative. Delay in operations.	No effect.	3
UV	Under voltage relay (Sheet 3-G5)	Safety device. Provides protection for lack of voltage.	Fails closed	Lack of crane power. Delay in operations.	No effect.	3
			Fails open	Crane inoperative. Delay in operations.	No effect.	3

Table 8. Flexhose FMEA – 30-Ton Bridge Crane								Pages 100 to 100
System/Subsystem: 30-Ton Bridge Cranes **PMN:** H70-1379							**Drawing No.:** SK-78-KL-14484 **Reference:**	
Find No. Qty NASA Part No.	**MFG Name MFG Part No.**	**Material**	**Fluid Media**	**Inside Dia. (in.)**	**Max Oper/Proof/ Burst Pressure (psig)**	**Bend Radius (in.)**	**Failure Effect On System Performance, Vehicle Systems, And/Or Personnel Safety**	**Crit Cat**
79K80260-4-0250 8 None	R50200CC-6- 0250	N/A	Hydraulic Fluid	5/16	1500/3000/6000	4	Failure would result in setting the drum brake. Possible hydraulic fluid contamination of a payload. Loss (damage) to a vehicle system.	2

4.3 COMPUTER INTERFACE ANALYSIS

This system does not use an LPS, INCS, or KCCS computer interface for control and/or monitoring of critical system functions identified in Section 4.1.

Appendix A. FAULT TREE AND HAZARD ANALYSIS

The Fault Tree Analysis, Hazard Analysis Worksheets follow.

The Hazard Reports associated with this system are listed below.

Shuttle Hazard Reports	
Hazard Report No.	**Title**
SAA36FT01-004 H01	OPF Crane (30 Ton) could drop the horizontal access bridge when removing an RTG from the payload bay, resulting in damage to the orbiter
SPC-K11863-86	Target tracking antenna can be impacted by the OPF 30-ton bridge crane movement
To view Hazard Reports, follow the path; USA Intranet Home Page - Data Warehouse (ADAM) – WebPCASS	

Industrial Hazard Reports	
Hazard Report No.	**Title**
LL-0012	Personnel required to perform work while beneath suspended loads during flight hardware processing at KSC/DFRF/CLS/VAFB
To view Hazard Reports, follow the path; USA Intranet Home Page – Departments – Mission Assurance, KSC – System Safety Engineering	

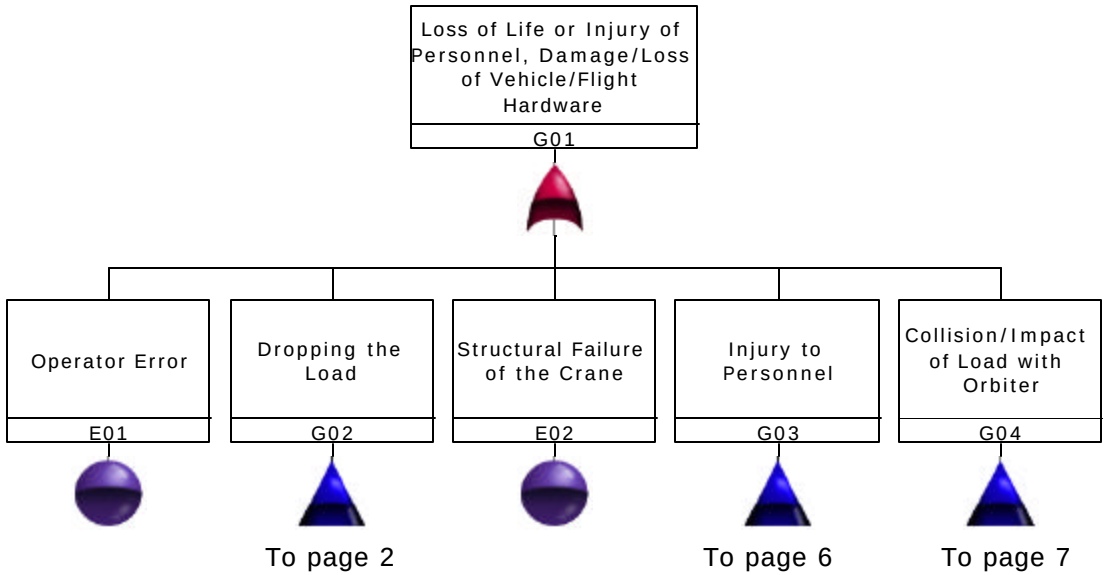
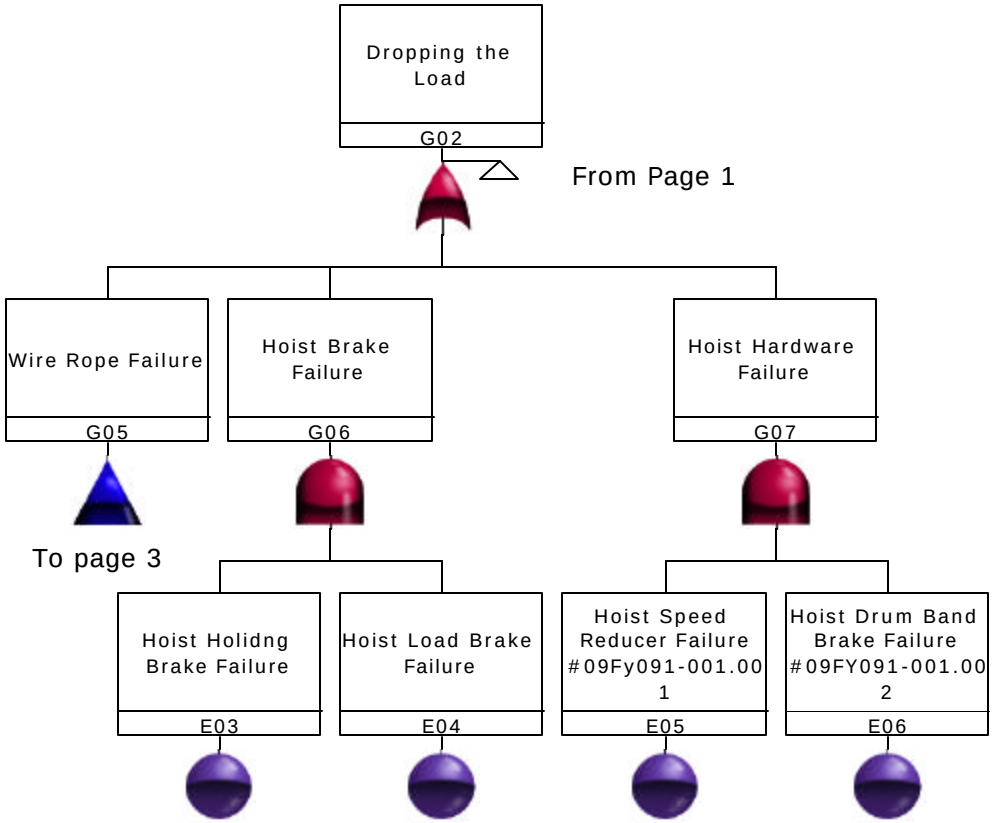
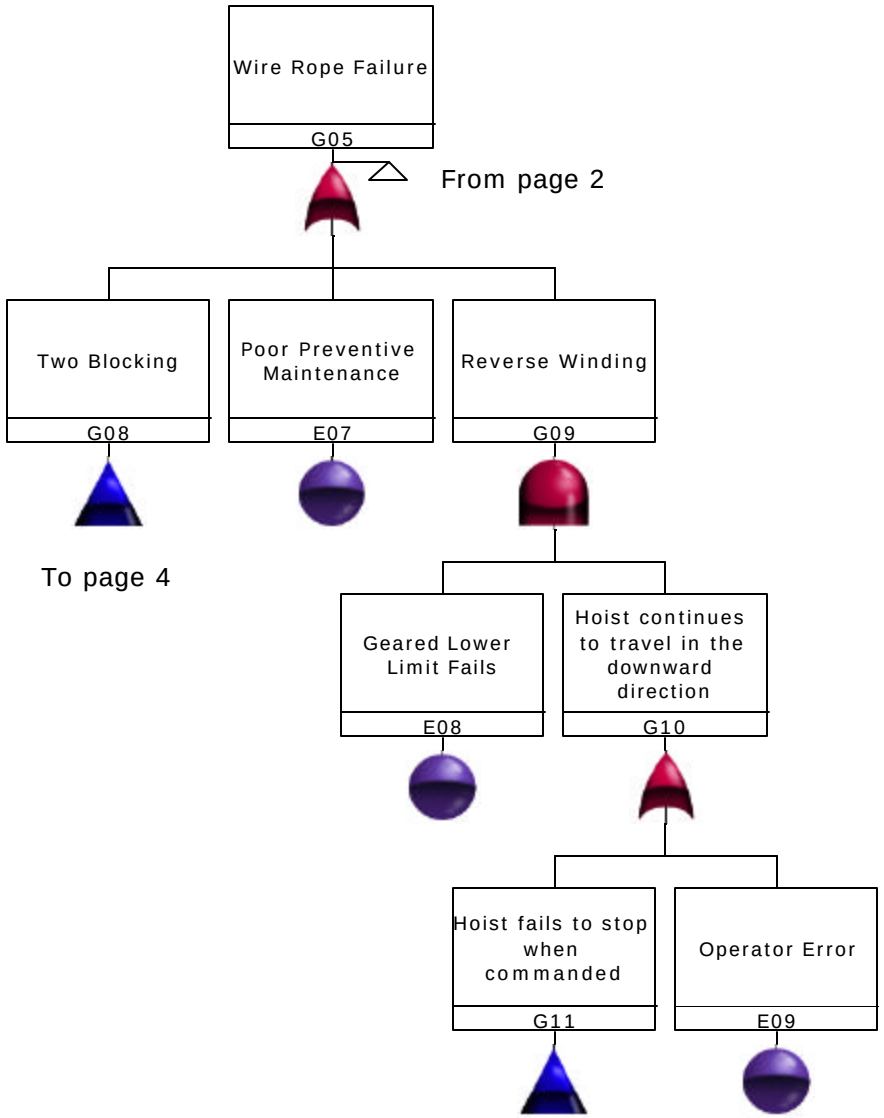
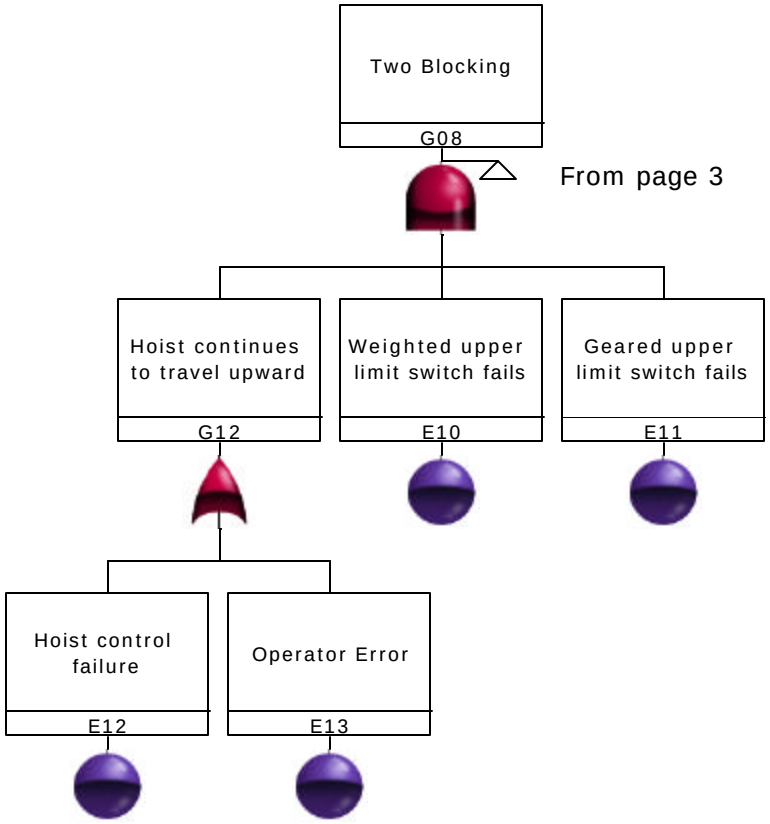
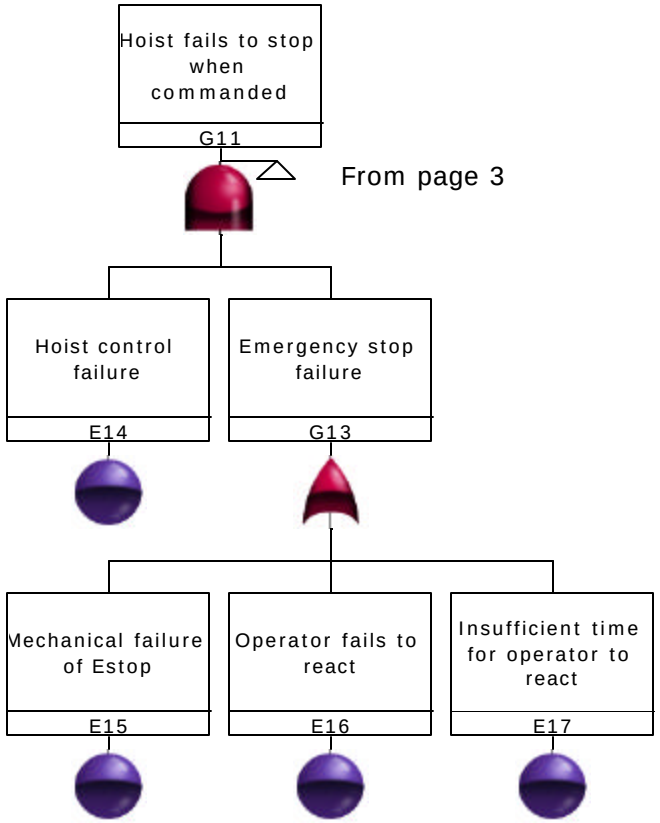


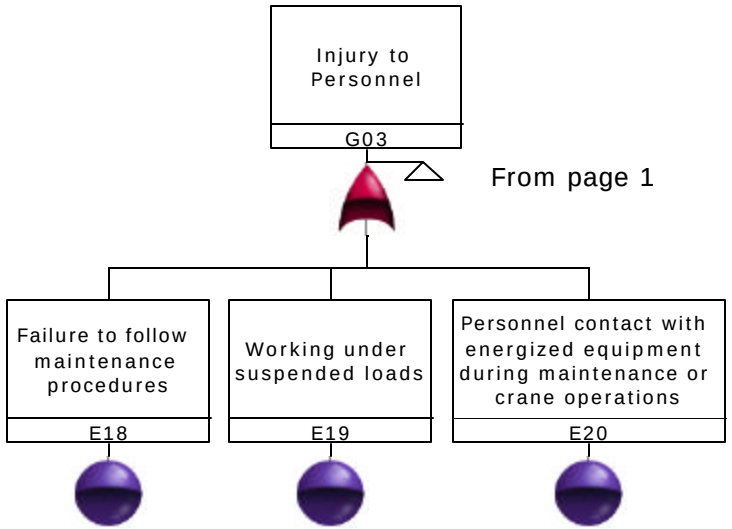
Figure 7. 30-Ton OPF Bridge Crane Fault Tree


Dropping the Load
G02
From Page 1
Wire Rope Failure
G05
Hoist Brake Failure
G06
Hoist Hardware Failure
G07
To page 3
Hoist Holidng Brake Failure
E03
Hoist Load Brake Failure
E04
Hoist Speed Reducer Failure #09Fy091-001.001
E05
Hoist Drum Band Brake Failure #09FY091-001.002
E06


Wire Rope Failure
G05
From page 2
Two Blocking
G08
Poor Preventive Maintenance
E07
Reverse Winding
G09
To page 4
Geared Lower Limit Fails
E08
Hoist continues to travel in the downward direction
G10
Hoist fails to stop when commanded
G11
Operator Error
E09
To page 5


Two Blocking
G08
From page 3
Hoist continues to travel upward
G12
Weighted upper limit switch fails
E10
Geared upper limit switch fails
E11
Hoist control failure
E12
Operator Error
E13


Hoist fails to stop when commanded
G11
From page 3
Hoist control failure
E14
Emergency stop failure
G13
Mechanical failure of Estop
E15
Operator fails to react
E16
Insufficient time for operator to react
E17


Injury to Personnel
G03
From page 1
Failure to follow maintenance procedures
E18
Working under suspended loads
E19
Personnel contact with energized equipment during maintenance or crane operations
E20

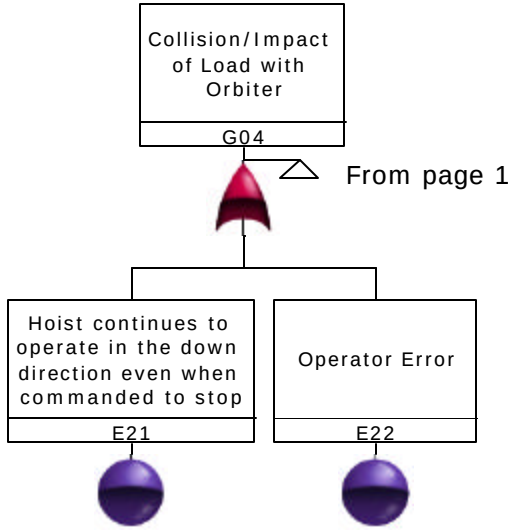

Collision/Impact of Load with Orbiter
G04
From page 1
Hoist continues to operate in the down direction even when commanded to stop
E21
Operator Error
E22

Table 9. Hazard Analysis Worksheet – H70-1379		Pages A-8 to A-12
System / Subsystem: 30-Ton Bridge Cranes		**Location:** OPF High Bays 1 and 2
Event No.	**Event Nomenclature (Hazard Cause)**	**Hazard Cause Elimination / Control Verification**
E01	Operator Error	NASA-STD-8719.9, Standard for Lifting Devices and Equipment, paragraph 4.6 requires that only trained and certified operators shall be authorized to operate the crane. OMI Q3119 requires that personnel have the following certifications: Certification 091, Fixed Cranes/Hoists E-stop Observer (T) Certification 094-1, Fixed Cranes/Hoist Opr/Cont/E-stop Observer (Level 1) (T) Certification 094-4, Fixed Cranes/Hoist Opr/Cont/E-stop Observer (Restricted) (T) OMI Q3119 states that no lifting operations shall be performed without a ground controller equipped with a communication and an observer/e-stop operator equipped with communication. Two certified operators will be in each cab during lifting operations. The crane operator will repeat commands before carrying it out, if it does not impede operations. If communications between the ground controller and crane operator is lost, operations will be stopped until communications are re-established.
E02	Structural Failure of the Crane	NASA-STD-8719.9, Paragraph 4.2.2 Labeling/Tagging of Cranes, item (a), requires the rated load be clearly marked on the side of the crane, and shall be clearly legible from the ground floor (OSHA requirement). The load lifted shall not exceed the rated load. NASA-STD-8719.9, Standard for Lifting Devices and Equipment, Paragraph 4.2.5 Structural, requires that structural design shall be in accordance with industry standards (ASME and CMAA) for material selection, welding, allowable stresses, design limitations, framing, rails, wheels, and other structural elements. NASA-STD-8719.9, Paragraph 4.3.1 requires that prior to first use, a Proof Load Test will be accomplished with a load as close as possible, but not to exceed, 1.25 times the rated load (-5/+0 percent) NASA-STD-8719.9, Paragraph 4.3.2 requires that an annual load test will be performed with a load equal to the rated load (+5/-0 percent). OMI Q6158 requires and performs an annual load test. OMI Q6158 performs an annual inspection of the crane structure for evidence of deformation or other signs of damage at welded and bolted connections. Structural members are checked for deformation, cracks, cracked welds, corrosion, loose fasteners, or other signs of deterioration.

Table 9. Hazard Analysis Worksheet – H70-1379		Pages A-8 to A-12
System / Subsystem: 30-Ton Bridge Cranes		**Location:** OPF High Bays 1 and 2
Event No.	**Event Nomenclature (Hazard Cause)**	**Hazard Cause Elimination / Control Verification**
E03	Hoist holding brake failure	NASA-STD-8719.9, Standard for Lifting Devices and Equipment, Paragraph 4.2.6.b (5) Mechanical, requires cranes used for critical lifts to have two holding brakes, each capable of bringing a rated load to zero speed and holding it. Holding brakes shall be applied automatically when power to the brake is removed. NASA-STD-8719.9, Paragraph 4.3.3.d states that each brake's ability to stop and hold a rated load be demonstrated. The brakes shall be tested to ensure it is able to hold a static load and stop a dynamic load. The operational test must demonstrate the ability of each brake to stop and hold a rated load. NASA-STD-8719.9, Standard for Lifting Devices and Equipment, Section 4, Overhead Cranes, has the following requirements for brakes: Daily: Paragraph 4.4.4 (c) requires that a certified operator, prior to first use each day the crane is used, perform a visual inspection of the brakes for excessive wear and contamination by excessive lubricants or foreign matter. Monthly: Paragraph 4.4.5.a (3), requires an inspection for those items in the daily inspection. Annual: Paragraph 4.4.5b(1), requires an annual inspection to include those requirements in the monthly inspection. In addition, inspect for wear in brakes, and evidence of a malfunction in braking devices. OMI Q6158 implements these requirements.
E04	Hoist load brake failure	See E03
E05	Hoist gearbox failure	The gearbox is a 1R critical item and the risk of failure has been accepted by the program. See the CIL sheet for acceptance rationale.
E06	Hoist emergency drum band brake failure	The emergency drum band brake is a 1R critical item and the risk of failure has been accepted by the program. See the CIL sheet for acceptance rationale.

Table 9. Hazard Analysis Worksheet – H70-1379		Pages A-8 to A-12
System / Subsystem: 30-Ton Bridge Cranes		**Location:** OPF High Bays 1 and 2
Event No.	**Event Nomenclature (Hazard Cause)**	**Hazard Cause Elimination / Control Verification**
E07	Poor preventive maintenance of the wire rope	NASA-STD-8719.9, Standard for Lifting Devices and Equipment, Section 4, Overhead Cranes, has the following requirements for wire rope: Daily: Paragraph 4.4.4(e) requires that a certified operator, prior to first use each day the crane is used, perform a visual inspection of the wire rope reeving for proper travel and drum lay, and inspect wire rope for obvious kinks, deformation, wire clips and/or damage. Monthly: Paragraph 4.4.5.a (3) requires an inspection of those items in the daily inspection and signs of deterioration and damage as outlined in paragraph 4.5.3.c of NASA-STD-8719.9. Paragraph 4.5.3 states that the need to replace wire rope shall be determined by a certified or otherwise qualified person, based on an evaluation of inspection results. If replaced, a new rope shall be proof load tested using the associated crane proof load value. Annual: Paragraph 4.4.5b(1) requires an annual inspection to include those requirements in the monthly inspection. Paragraph 4.7v, Operations, states that the load shall not be lowered below the point where less than two full wraps of the rope remain on the hoist drum. OMI Q6158 requires monthly inspection and annual lubrication of the wire rope.
E08	Geared lower limit switch fails	OMI Q3119 requires that at the beginning of each operator's shift, upper-geared limit switches of hoist shall be checked under no load. The load block will be inched very slowly into the geared limit switches (slow and fast speeds). The operator will verify if the upper movement stops when the gear limit is encountered.
E09	Operator Error	See E01
E10	Weighted upper limit switch fails	OMI Q3119 requires that at the beginning of each operator's shift, upper-geared limit switches of hoist shall be checked under no load. The load block will be inched very slowly into the geared limit switches (slow and fast speeds). The operator will verify if the upper movement stops when the gear limit is encountered.
E11	Geared upper limit switch fails	See E08

Table 9. Hazard Analysis Worksheet – H70-1379		Pages A-8 to A-12
System / Subsystem: 30-Ton Bridge Cranes		**Location:** OPF High Bays 1 and 2
Event No.	**Event Nomenclature (Hazard Cause)**	**Hazard Cause Elimination / Control Verification**
E12	Hoist control failure	OMI Q3119 performs pre-operational checks on the crane, including E-stop and observer pre-operation responsibilities.
E13	Operator error	See E01
E14	Hoist control failure	See E12
E15	Mechanical failure of emergency stop	OMI Q3119 provides instructions for visual inspections and pre-operation testing of the E-stop system. OMI Q6158 calls for monthly and quarterly maintenance on the emergency brakes (emergency drum band brakes).
E16	Operator fails to react	OMI Q3119 provides steps for the emergency stop operator to monitor all lifts, be equipped with a handie-talkie 2-way radio and be in visual contact with ground controller for radio communication backup. They must also verify crane e-stop is pendant is connected in a location near lifting area and ground controller and verify indicator lamp is illuminated.
E17	Insufficient time for operator to react	OMI Q3119 provides steps for the emergency stop operator to command an emergency stop when there is evidence of impending damage due to a load (or crane) movement without sufficient time for a normal stop. The observer should be aware of the task being performed and its location relative to obstacles. Positioning should allow unobstructed view of operation. Call stop to avoid accidents/incidents.
E18	Failure to follow maintenance procedures	NASA-STD-8719.9, Standard for Lifting Devices and Equipment, Paragraph 4.5 Maintenance, requires that maintenance be performed in accordance with the manufacturers recommendations. OMI Q6158 performs monthly, semi-annual and annual required maintenance and annual load test and hook magnaflux check.
E19	Working under suspended loads	See Hazard Report LL-0012.

Table 9. Hazard Analysis Worksheet – H70-1379		Pages A-8 to A-12
System / Subsystem: 30-Ton Bridge Cranes		**Location:** OPF High Bays 1 and 2
Event No.	**Event Nomenclature (Hazard Cause)**	**Hazard Cause Elimination / Control Verification**
E20	Personnel contact with energized equipment during maintenance or crane operations	KHB 1710.2 “KSC Safety Practices Handbook”, USA Ground Operations Operating Procedure, USA002433 “Lockout/Tagout and Do Not Use or Operate Programs” states that all affected, authorized, and other employees shall annually complete two training courses: QG20A-LSC, “Site/Area Specific Safety Training and QG111-LSC, “Lockout/Tagout”. Personnel will lockout and tag any system prior to de-energization and then verifies the equipment is truly de-energized before any maintenance begins. Certification 094-1, Certified Fixed Crane Operator, TG34A, LSC-CR, Fixed Crane Operator Safety Course trains operators on safety requirements of the crane operation including control cabinets.
E21	Hoist continues to operate in the down direction even when commanded to stop	OMI Q3119, Safety Instructions, state that whenever a critical load is within 3 feet of any structure, personnel shall operate the crane at slow speed for all crane motions. This allows for
E22	Operator error	See E01

Appendix B. CRITICAL ITEMS LIST

USA Ground Operations 1R Non-CIL Sheet

1R Non-CIL Item: Gearbox
Criticality Category: 1R
NASA Part No: None
Total Quantity: 4
Mfg/Part No: Fulton / None
System: 030-Ton Bridge Crane

Find No.	Qty	Area	PMN	Baseline	Drawing / Sheet
None	2	OPF-1	H70-1379	380.00	Fulton Shipyard 1205 / 3
None	2	OPF-2	H70-1379	380.00	Fulton Shipyard 1205 / 3

Function:

Transmits power from the hoist to the drum.

Failure Mode No. Failure Mode	Failure Cause Failure Effect	Detection Method Time to Effect	Crit Cat
09FY091-001.001 Gear disengagement	Excessive gear wear, structural failure of gears or shaft Load would drop. The hoist holding brake will be ineffective. Emergency drum brake would automatically be activated and safe the load.	Drum rotary limit switch (LS-1) monitors for over speed. Seconds	1R

ACCEPTANCE RATIONALE

Redundancy Screens: **Pass/Fail**

A	Item is verifiable during normal ground operations	Pass
B	Item loss is readily detectable by the ground crew	Fail
C	Loss of all redundant items cannot result from a single cause	Pass

Conforms to NSTS 08080-1: N/A

Test and Inspection:

OMI Q6158 performs monthly inspection of the drum for any condition that could indicate an internal problem with the gearbox.

OMI Q6158 performs semi-annual maintenance on the crane. During this maintenance, inspect the hoist drum and pinion gear, bull/pinion gear set for pitting, wear or damage, and for proper lubrication.

OMI Q6158 performs annual maintenance on the crane. Annual maintenance includes those requirements in the semi-annual maintenance and will require that an oil sample will be taken for analysis.

NASA-STD-8719.9 requires new or modified cranes shall undergo a proof load test not to exceed 1.25 times the rated capacity of the crane. Cranes used frequently for critical lifts shall be load tested at the rated capacity annually, as well as operational test performed.

OMRS File VI requires the performance of an annual rated load test and an operational test.

USA Ground Operations 1R Non-CIL Sheet

1R Non-CIL Item: Emergency Brake, Drum Band Brake
Criticality Category: 1R
NASA Part No: None
Total Quantity: 4
Mfg/Part No: Fulton Shipyard / M-2010
System: 030-Ton Bridge Crane

Find No.	Qty	Area	PMN	Baseline	Drawing / Sheet
None	2	OPF-1	H70-1379	380.00	Fulton Shipyard 1205 / 3
None	2	OPF-2	H70-1379	380.00	Fulton Shipyard 1205 / 3

Function:

The emergency brake is hydraulically released and spring set. While the crane is in operation the emergency brake is normally released by an energize hydraulic valve solenoid coil, which applies hydraulic pressure again the spring action, thus holding the emergency brake in the released position. In event of an overspeed of the hoist drum, loss of power to the crane or if the emergency brake stop button is pressed, the solenoid valve will be de-energized, releasing the hydraulic pressure, allowing the brake to set and hold the load.

Failure Mode No. Failure Mode	Failure Cause Failure Effect	Detection Method Time to Effect	Crit Cat
09FY091-001.002 Fails to engage	Solenoid valve fails to relieve hydraulic pressure to allow the emergency brake to set, spring failure, worn brake pads, overspeed detection circuit failure. Loss of emergency drum brake capability. Requires prior failure of both the hoist holding brake and hoist load brake. Load would drop uncontrolled if couple with failure of gearbox. (Motor brakes would be ineffective).	Visual Seconds	1R

ACCEPTANCE RATIONALE

Redundancy Screens: **Pass/Fail**

A	Item is verifiable during normal ground operations	Pass
B	Item loss is readily detectable by the ground crew	Fail
C	Loss of all redundant items cannot result from a single cause	Pass

Conforms to NSTS 08080-1: N/A

Test and Inspection:

OMI Q6158 performs monthly inspection of the hydraulic fluid level.

OMI Q6158 performs semi-annual maintenance on the crane. During this maintenance, inspect the hoist drum emergency brake for excessive wear of brake shoes, secuirty hardware and any signs of damage. Check hydraulic system for leaks.

OMRS File VI requires the performance of an annual rated load test and an operational test to ensure that the emergency brake, hydrauilc dump valve and overspeed limit switch operates properly.